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2^{nd} Edition

♦ These are special *Learning About Learning* activities and homework that focus on your own learning, the learning of children or the learning of scientists (nature of science).

CHAPTER 2

Developing Ideas

ACTIVITY 1: Interactions and Force

Purpose

In Chapter 1 you developed some ideas about how to describe contact push/pull interactions between objects in terms of a transfer of mechanical energy between the objects. For example, for a soccer player kicking the ball, previously we might have said:

"There is a contact push/pull interaction between the player's foot and the ball. Mechanical energy is transferred from the foot to the ball"

However, scientists often use a different way of describing the **same** interactions, not in terms of energy transfers and changes, but in terms of the pushes and pulls (which they call **forces**) that the objects exert on each other. So, for the example above, we could also say:

"There is a contact push/pull interaction between the player's foot and the ball. The foot pushes the ball" **or** *"The foot exerts a force on the ball."*

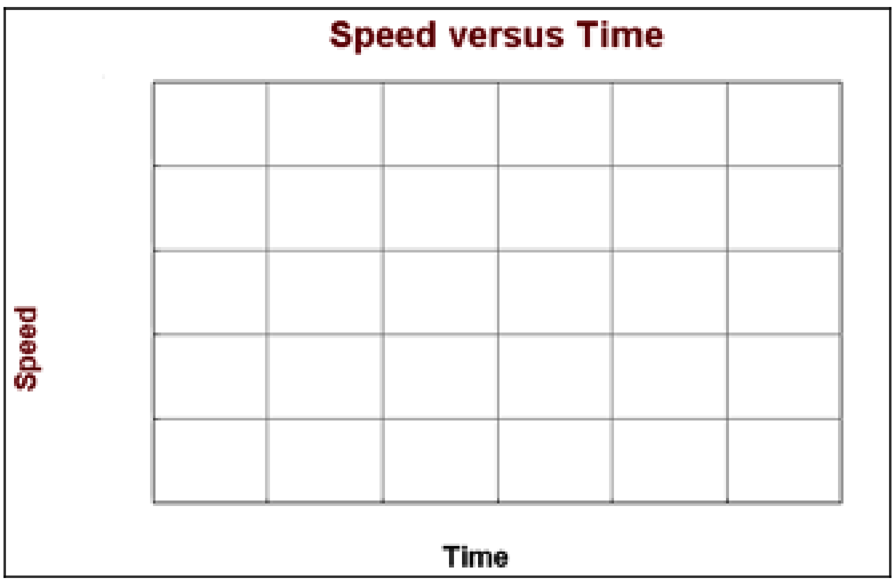
In this cycle you will be investigating the effects that forces have on the motion of objects. We will start by examining how we can recognize when a force is acting on an object, and when it is not.

How does an object move when a force is acting on it?

Initial Ideas

Think about a soccer player kicking a stationary ball. As he interacts with it, by kicking it, the ball starts to move. After the kick, the ball rolls across the grass and gradually comes to a halt.

Sketch a speed-time graph for the motion of the ball, from the moment the player's foot first contacts it until it comes to a halt again.



Using a colored pencil, indicate the period on the graph during which the foot was in contact with the ball. Explain your reasoning.

Using a different colored pencil, indicate the period on the graph during which there was a force pushing the ball forward. Again, explain your reasoning.

Draw a picture of the ball and use arrows to show what **forces** (if any) you think are acting on the ball **after** the foot has lost contact with it, but before it stops

Participate in a whole class discussion about these questions. Make a note of any ideas or reasoning that are different from those of your team.

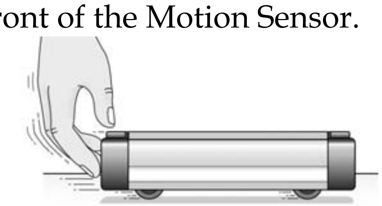
Collecting and Interpreting Evidence

Experiment #1: Is the motion of the cart after it has been pushed the same as during the push?

You will need:

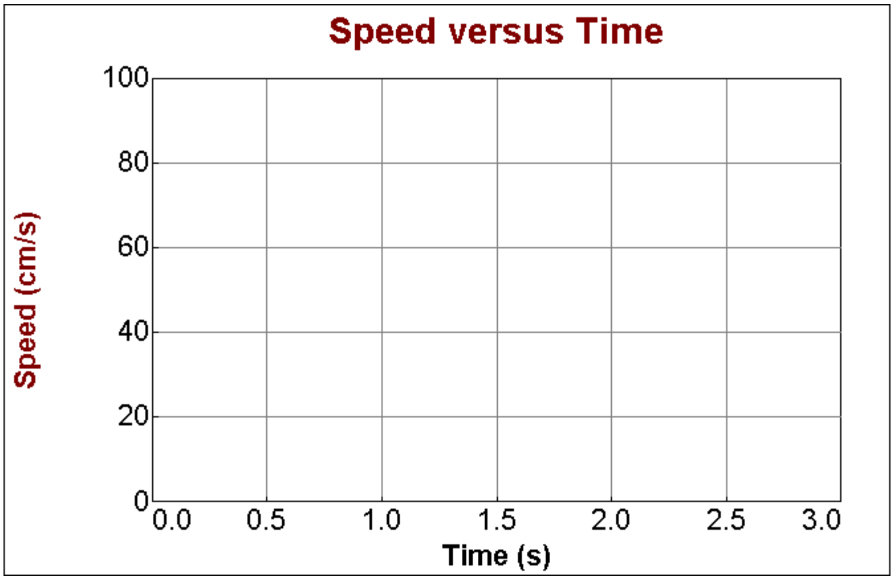
- Low-friction cart
- Track
- Access to a Motion Sensor connected to a computer

STEP 1: Open the Motion Sensor data collection file for this activity. Place your cart at rest on the track about 20 - 30 cm in front of the Motion Sensor. Start collecting Motion Sensor data and then have one of your team members give the cart a **gentle** push away from the sensor with their hand.



While the cart is moving, and before the data collection stops, give the cart two or three more pushes, in the **same direction** as the first push. (Stop the cart when it reaches the other end of the track.)

Sketch the speed-time graph for the motion of the cart.

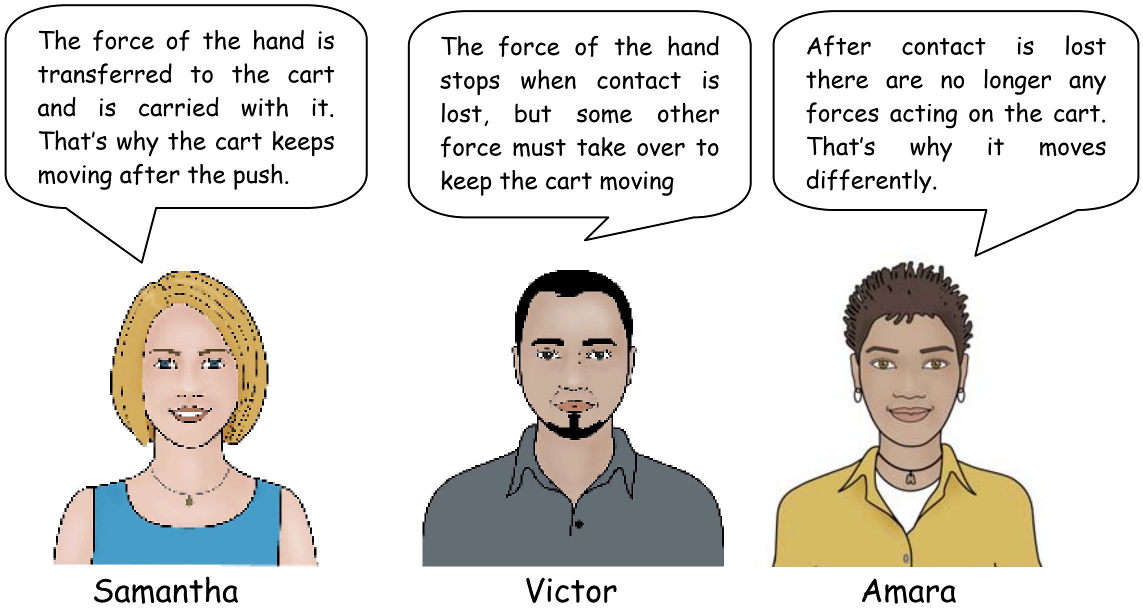


Each time the hand interacts with the cart, what happens to the cart's speed? Does it speed up quickly, slow down quickly, or move at a reasonably constant speed?

During the periods when the hand is not interacting with the cart what happens to the cart's speed? Does it speed up quickly, slow down quickly, slow down slowly, or move at a reasonably constant speed? Why do you think this is?

What evidence would you look for to tell you that a force is acting on the cart? To illustrate your thinking, use a colored pencil to indicate on the speed-time graph above the sections of the graph during which you think there is a force pushing the cart forwards. Explain your reasoning below.

STEP 3: Three students are discussing the motion of the cart and the force acting on it. They all agree that while the hand is pushing it there is a force acting on the cart, but have different ideas about what happens during the periods when the hand is not in contact.

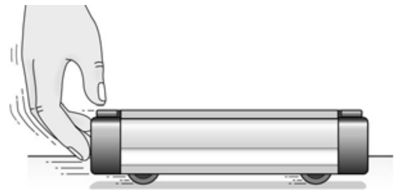


Do you agree with Samantha, Victor, or Amara, or with none of them? Explain your thinking.

Experiment #2: What happens to the cart when it is given a continuous push?

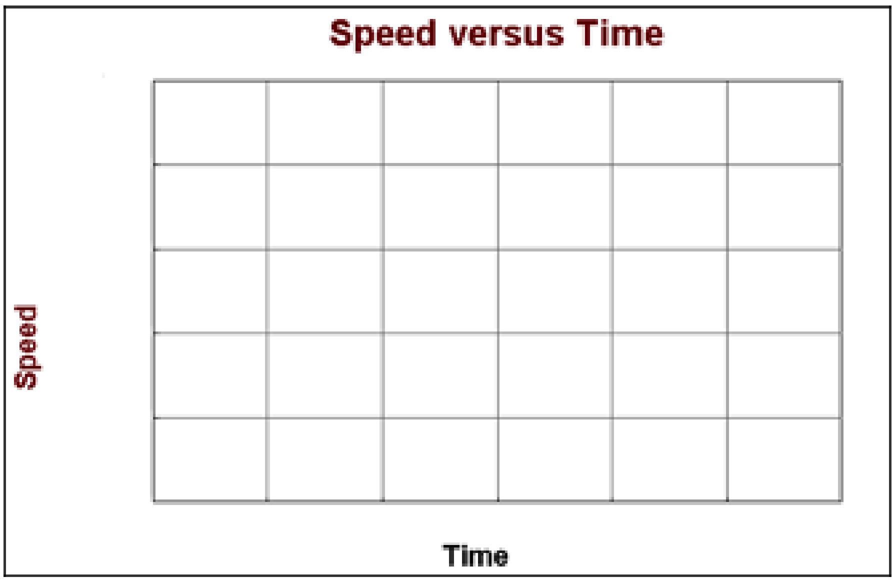
You will need:

- Low friction cart
- Track
- Fan unit
- Access to a Motion Sensor connected to a computer

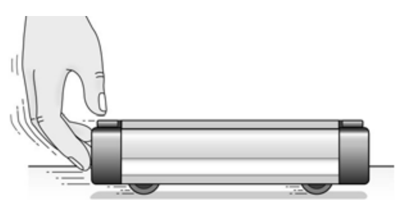


STEP 1: In the previous experiment you started a cart moving by giving it a quick push. Now, suppose instead you were to keep pushing the cart continuously with a **constant strength.**

What do you think the motion of the cart would be like under these circumstances? Sketch a speed-time graph to illustrate your thinking.



Briefly explain your reasoning.



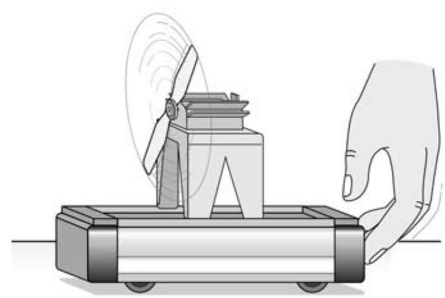
STEP 2: Place the cart near one end of the track (or table). Each member of your team should try using **one finger** to push the cart along the track. (Make sure you push the cart from behind; do not grip it with your fingers.) Try to maintain a constant strength push as the cart moves.

How does the cart seem to behave as you push it?

How easy did it seem to maintain a continuous, constant-strength, push? Why do you think this is?

Most people find it very difficult to maintain a continuous push of a constant strength. We will now check to see if there is a better way to arrange for such a force to act on the cart.

STEP 3: Fix the fan unit to the cart and place it, at rest, on the track (or table). Turn the fan unit on and have one of your team place a finger in front of the cart to stop it from moving. This person should concentrate on the push they feel from the cart while the fan is running.



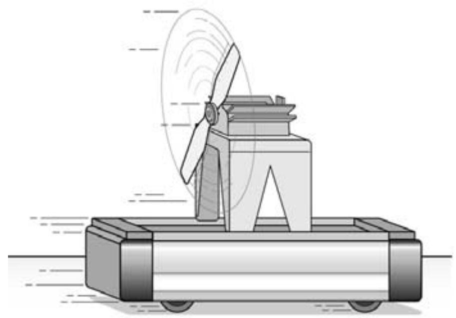
At the same time another team member should listen to the sound the fan unit makes while it is running. Keep the fan running for several seconds and then turn it off.

How does the push of the cart seem to behave while the fan is running? Does the push seem to stay constant or does it seem to increase or decrease significantly?

Does the sound that the fan makes change as it is running, or does it sound about the same the whole time?

Do you think the fan unit exerted a constant strength force on the cart while it was running? What evidence supports your idea?

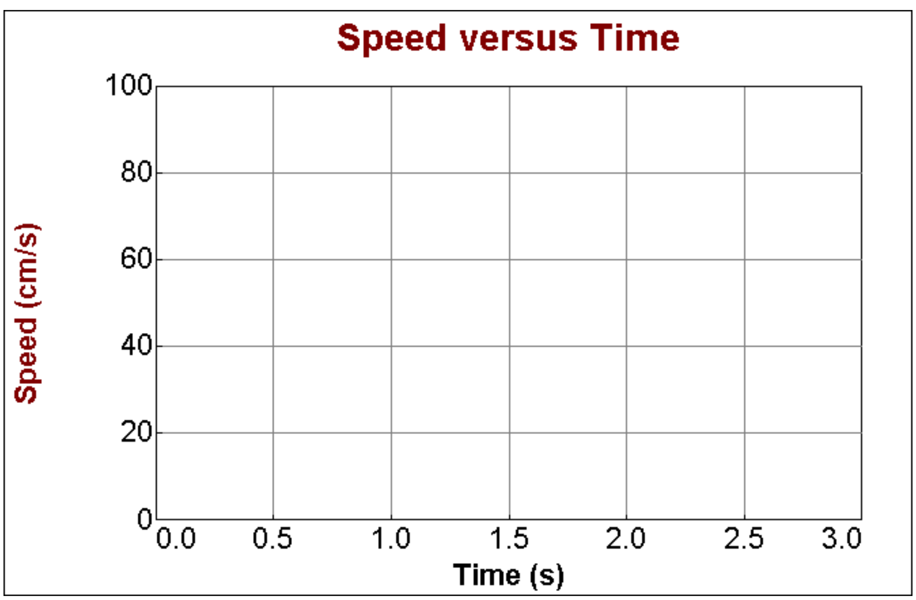
STEP 4: Open the Motion Sensor data collection file for this activity (if it is not already open). Place the cart about 20 – 30 cm in front of the Motion Sensor and turn the fan on. Start the data collection and then release the cart. (Do **not** give it any sort of push or pull with your hand.) One team member should listen carefully to the sound of the fan while the cart is moving.



Carefully stop the cart before it reaches the other end of the track and turn the fan unit off.

Do you think the fan unit exerted a constant strength force on the cart as it moved along the track? What evidence do you have to support your answer?

Sketch the speed-time graph for the motion of the cart below.

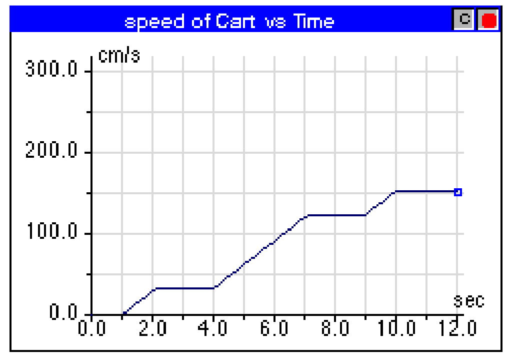


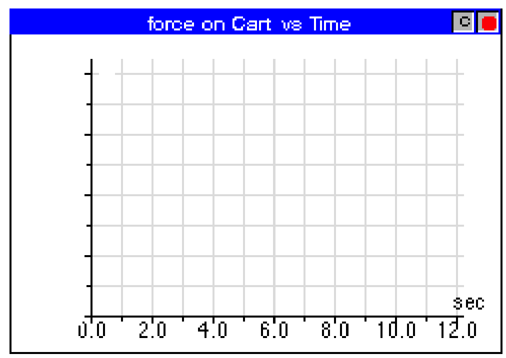
What does the speed-time graph tell you about the speed of the cart while the fan unit was pushing it?

Does the behavior of the cart agree with the prediction you made at the beginning of this experiment?

Simulator Exploration #3: How does your thinking compare to scientists' models?

STEP 1: On the right is a speed-time graph taken from an *I&M Simulator* set-up that models the experiment in which you pushed the cart two or three times.





Indicate the periods on the speed-time graph when you think the cart in the simulator was being pushed. How do you know?

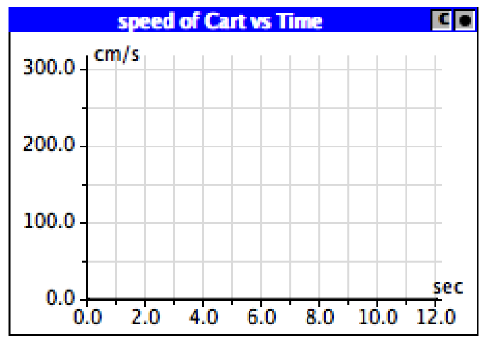
The *I&M Simulator* can also 'measure' the force acting on the cart in the simulator model. On the blank force-time graph above, sketch how you think the force acting on the simulator cart varies (if at all) during the same 12-second time period shown on the speed-time graph. (Note: It is only the shape of the graph that is important for now, so no values for the force are shown.)

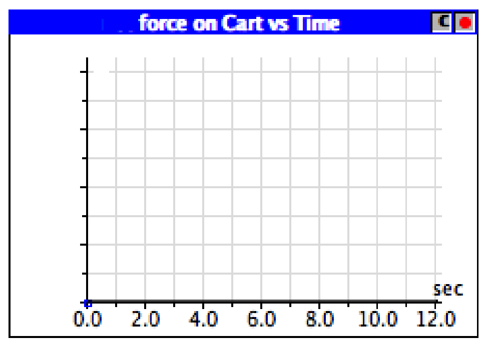
Explain the reasoning that led you to draw your force-time graph the way you did.

STEP 2: Open the simulator set-up file for this activity. The set-up shows a cart on a track, together with speed-time and force-time graphs.

While the simulator is running you can give the cart a 'push' by pressing on the spacebar of your computer keyboard. The push will continue (at a constant strength) as long as you hold the spacebar down. The simulator will stop on its own after 12 seconds.

Run the simulator a few times (remember to click 'rewind' to get back to the start) and check that you understand how the spacebar 'push' works. When you are ready, try to produce a speed-time graph as close to that shown in STEP 1 as you can.





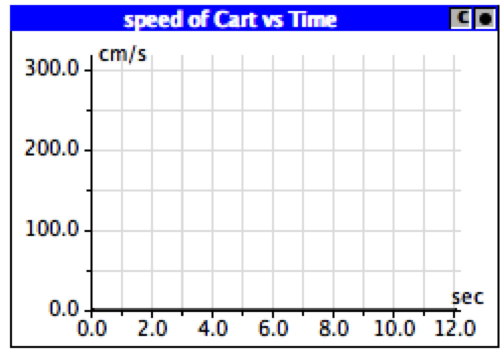
Sketch the speed-time and force-time graphs from the simulator.

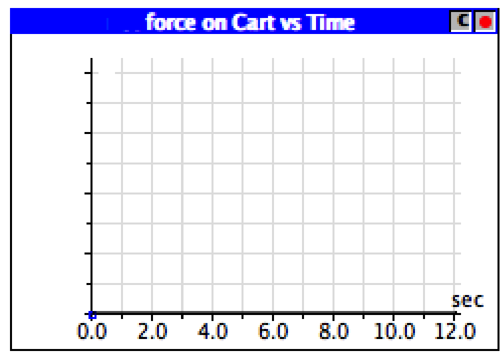
During the periods when the simulator cart was being 'pushed' was there a force acting on it? What evidence from the simulator graphs supports your idea?

During the periods in between the pushes, was there a force acting on the simulator cart? Again, what evidence from the graphs supports your idea?

STEP 3: Run the simulator again, but this time hold the spacebar down to apply a **continuous constant strength force** to the cart. (As the fan unit did to the real cart.)

Sketch the speed-time and force-time graphs from the simulator.



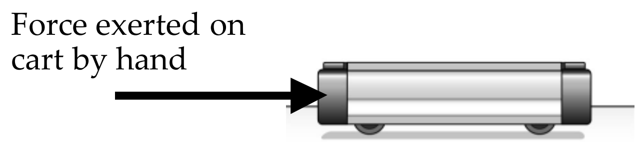


Based on the evidence you have gathered in this activity, what happens to the speed of an object while a single force is acting on it in the same direction as its motion?

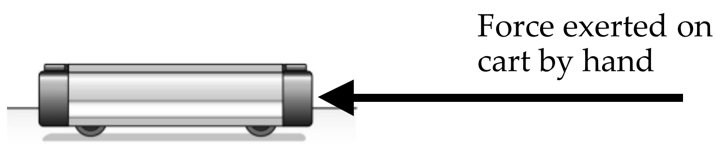
Forces and Force Diagrams

The pushes you used in this activity are examples of forces. Whenever one object is pushing or pulling on another object we say it is exerting a force on the other object. This means that the pushes and pulls you used in Chapter 1 to investigate contact push/pull interactions could also be described in terms of forces exerted on the cart by a person or another cart.

Just as with the energy description of contact push/pull interactions you developed in Chapter 1, we can also draw a diagram to help us analyze and explain the force description of the same interactions. In such a **force diagram**, we identify the object of interest and all the forces (pushes and pulls) being exerted on it by **other** objects at a **particular moment in time**. We represent these forces with 'force arrows' on the diagram, which are labeled to show what they represent. For example, the force of your hand pushing the cart could be represented like this:

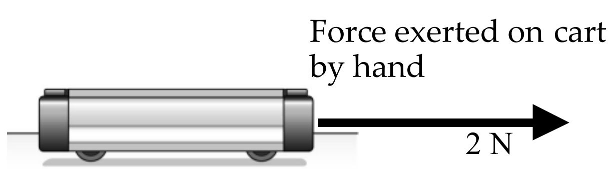


As you might expect, the direction of these force arrows indicates the direction of the forces they represent. In addition, the length of the arrows indicates the relative strengths of the forces. So, for example, if you pushed the cart in the other direction, with a stronger push, the force diagram would look like this (note the longer arrow):



Notice that the force diagram shows only one of the objects involved in the interaction (the cart), and that the other object involved (the hand) is only mentioned in the labeling of the arrow representing the force it is exerting. In this sense these force diagrams are very like the Input/Output (I/O) energy diagrams you drew at the end of Chapter 1.

The strength of a force is measured in units of newtons (N), named in honor of Sir Isaac Newton, a famous English scientist you will learn more about later on. Sometimes it may be necessary to add information on the strength of a force to a force diagram. For example, if a hand pulls on a cart with a force of 2 N, that would be represented by the following diagram[1]:



[1] As you saw in Chapter 1, a push and a pull of the same strength have exactly the same effect on the motion of an object. Thus we could equally well represent this pull to the right using exactly the same force arrow as we would use for a push to the right. Since the effect is the same, distinguishing between pushes and pulls is simply a matter of choice. In this course, we will always draw force arrows on the side of the object from which the force is applied. Hence, a push will always be represented by a force arrow pointing toward the object, and a pull will always be represented by an arrow pointing away from the object.

Finally, if the object we are concerned with is in motion at the moment in time for which we are drawing the force diagram, it is sometimes important to know in which direction the object is moving. We can show this by drawing a speed arrow above the object (just like the speed arrow in the *I&M Simulator*). (We use a half-arrow so as not to confuse it with the force-arrows, since it represents the speed of the cart, **not** a force acting on the cart.) The length of the speed arrow represents the relative speed of the object. For example, when you gave the moving cart a push in the same direction as its motion, the force diagram for a moment in time during your push would look like this:

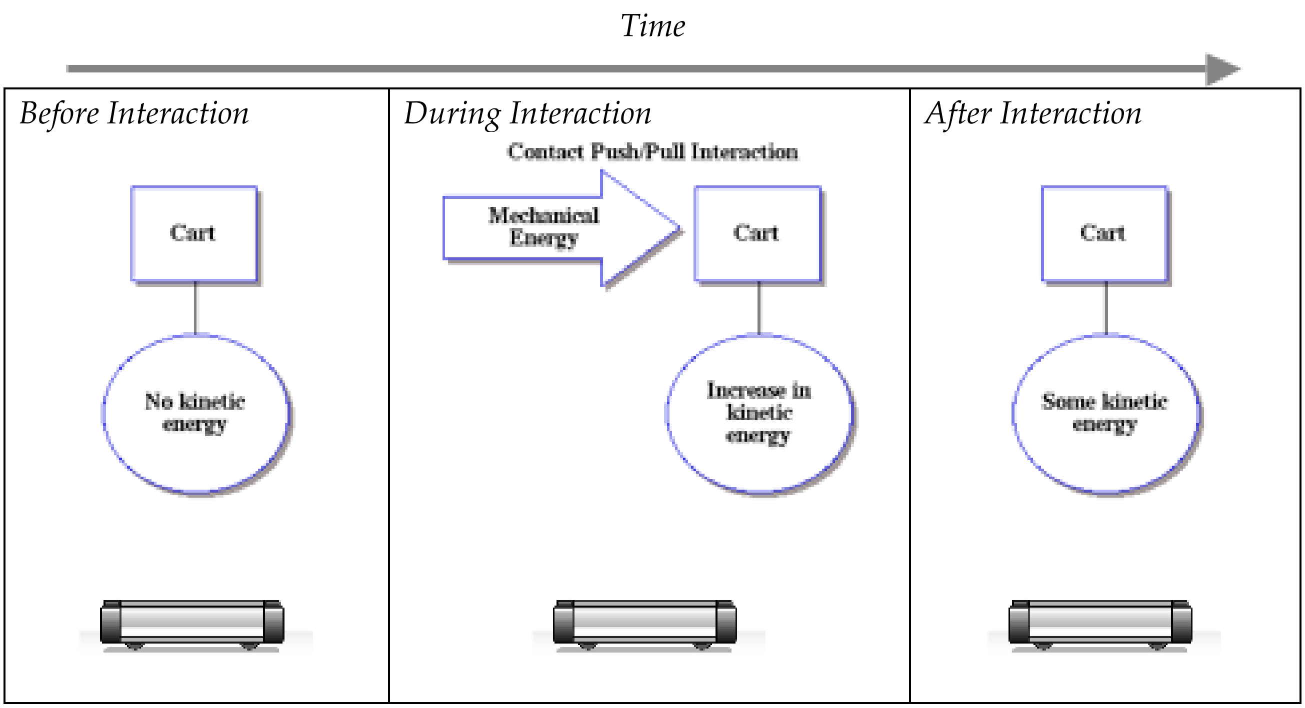
Note that the speed arrow only tells about the speed of the object at the particular moment in time for which the force diagram is being drawn. It does not tell anything about whether the object's speed is in the process of changing, or whether it is remaining constant.

You may have noticed that all the situations discussed above show only one force acting on the cart. It is certainly possible for more than one force to act on an object at the same time, but it is important to understand the effect of a single force before considering situations involving multiple forces. Thus, in the first few activities in this chapter, you will study the effect that a single force has on an object.

Comparing Force and Energy Diagrams

To help you start thinking about how force and energy ideas of describing contact push/pull interactions relate to each other, consider the situation of a stationary cart that is given a quick shove with a hand to start it moving. Shown below is a timeline of I/O energy diagrams showing how the energy transfer to the cart and changes in its kinetic energy are related to the interaction.

Below the energy diagrams are three pictures of the cart. Use these pictures to draw force diagrams, representing the force (due to the contact push/pull interaction between the hand and the cart) acting on the cart at the same three points in time as the energy diagrams. (Be sure to include force and speed arrows as you think appropriate. However, if you think there is no force acting at a particular time, then do not draw a force arrow.)



Summarizing Questions

S1: If a cart is at rest and a single force acts on it, what happens? If the same force continues to act on the cart what happens to the cart's speed?

S2: In general, during the time a single force with a **constant strength** acts on a moving object, in the **same direction as its motion**, what is the object's motion like? (Does it move at a constant speed, does its speed continuously increase, or does the speed only increase at first and then become constant after a short time?) What evidence from this activity supports your thinking?

S3: When you were using your finger to try to push the cart with a constant strength force, you probably noticed the cart was 'getting away' from you. (If not, try it again.) Why do you think the cart behaved in this way?

S4: Suppose that, while the cart was being pushed along the track by the fan unit, a wire suddenly broke so that the fan unit stopped pushing on the cart. What do you think would happen to the speed of the cart? Explain your reasoning.

S5: When you gave the cart a quick shove, at what moment do you think the force of the hand stopped acting on the cart? What evidence from this activity supports your idea?

S6: During a contact push/pull interaction, what do you think is transferred from the source to the receiver: energy, force, both, or neither? Explain your reasoning.

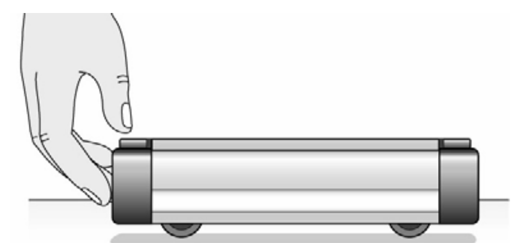
Participate in a whole class discussion to go over your answers to the Summarizing Questions and force diagrams.

Writing Scientific Explanations using Force Ideas

As previously stated, the contact push/pull interactions you are examining in this chapter are the same as those you were introduced to in Chapter 1. However, whereas in Chapter 1 you described these interactions in terms of ideas about energy transfers and changes, in this chapter you are developing ideas about forces and their effects that allow you to think about these same interactions in a different way.

The process of writing scientific explanations of phenomena using force ideas is very similar to the process you used in Chapter 1 when using energy ideas. However, instead of drawing an energy diagram, you should draw a **force diagram.** Also, instead of writing a narrative that describes the behavior of an object in terms of energy transfers and changes, you should do so in terms of the **forces** acting on the object and the effect they have on its motion (if any). When writing your scientific explanations (or evaluating those of others) you should keep in mind the criteria of *accuracy*, *completeness*, *logical reasoning* and *clarity* introduced in Chapter 1.

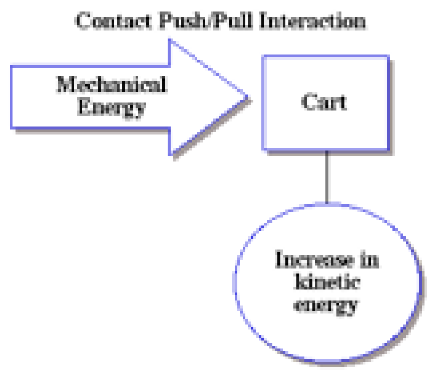
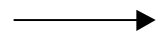
To illustrate the similarities between energy-based and force-based explanations, consider the following two parallel explanations of why a stationary cart begins to move when it is given a quick push by someone's hand.



Note: These explanations do not mention friction since we have not yet considered its effects in developing our ideas about forces. However, since we are dealing with a low-friction cart it can be assumed that the effects of friction are negligible.

Explanation: Why does a stationary cart begin to move when it is pushed?

Describe the situation using a diagram:

Energy Diagram	*Force Diagram*
	

Write the narrative:

During the contact push/pull interaction between the hand and the cart, there is a transfer of mechanical energy to the cart. According to the idea of Conservation of Energy, since there is no energy output, this input of energy must be accounted for completely by an increase in the kinetic energy of the cart. Since the cart is initially at rest, this increase in kinetic energy means that the cart starts moving.	The only force acting on the cart is that exerted by the hand. When a single force acts on an object at rest, the object starts to move in the direction of the force, so the cart starts to move in the direction of the force exerted by the hand.

So one explanation says that the cart starts to move because Conservation of Energy suggests that the mechanical energy input to the cart results in an increase in its kinetic energy, while the other says it moves because the hand exerts a force on it during the interaction between them. Which explanation is better? They are **both** good – they are just two different ways of looking at the **same interaction**, one based on the ideas of energy, the other on the ideas of forces. Further, as you are seeing in this activity, though these two sets of ideas are different, they are closely related.

The previous explanation was meant to show you how both energy and force ideas can be used to explain the same phenomenon. For the remaining explanations in this Chapter you should consider, and use, **only** force ideas. In this activity you saw that a cart with a fan unit attached started to move when the fan was turned on, and continued to speed up as it moved along the track. You should now use a general idea you developed about force and motion in this activity to write a scientific explanation for why this happened in this particular case.

Explanation: Why did the cart with a fan-unit attached continue to speed up as it moved along the track?

Describe the situation using a diagram: (Draw a force diagram for the cart while it is moving along the track and being pushed by the fan unit.)

Write the narrative: (Use the general idea you developed in this activity about what happens to the speed of a moving object when a continuous force acts on it in the same direction as its motion.)

Participate in a class discussion about this scientific explanation.

ACTIVITY 1 HW: Pushing a Skateboarder

Name:________________________________ Date:_______________ Group: ______

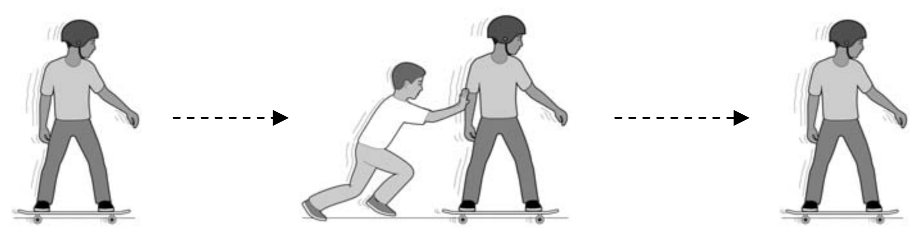
Purpose

In this homework activity you will practice using your developing ideas about how the motion of an object is related to the force acting on it.

Initial Ideas

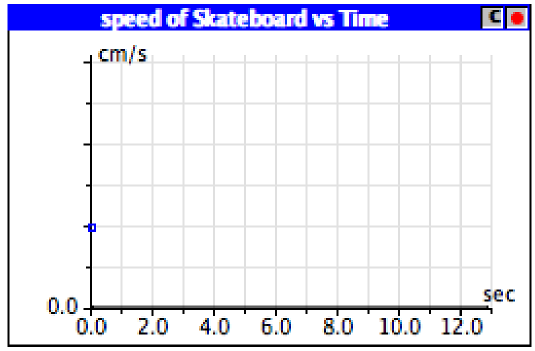
Imagine you see your friend **coasting** toward you on his skateboard. (How he started moving is not a concern here.)

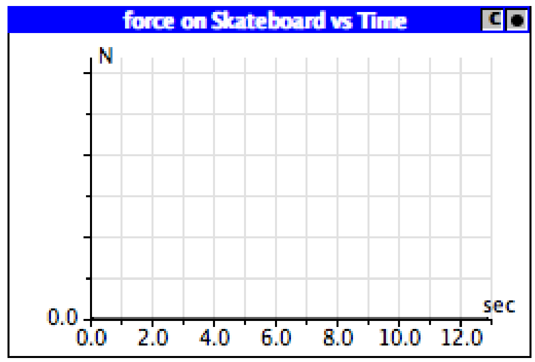
- From the moment you first see him it takes 4 seconds for him to reach you.
- As he reaches you, you begin to push him in the same direction as his motion, with a **constant strength push**. You continue to push in this way, moving with him, for a further 4 seconds, and then you stop pushing.
- Your friend continues to move, coasting in the same direction, for yet a further 4 seconds.



What do you think the motion of your friend would be like (speeding up, slowing down, or constant speed) during each of the 4-second periods described above? Would they all be the same or would they be different? Explain your reasoning. (Note: Assume the skateboard is well lubricated, so that the effects of friction between the parts of the skateboard and between the skateboard and ground can be ignored.)

Sketch what you think the speed-time and force-time graphs for your friend would look like for the whole 12-second period described above. *(You do not need to worry about particular values for the speed and force. However, you do need to pay attention to the time axis so that any corresponding 'events' in the two graphs line up with each other.)*





Explain why you drew the graphs the way you did.

Using the pictures of the skateboarder below, draw a separate force diagram for each indicated moment in time. (Use your predicted speed-time and force-time graphs above to guide you.) Be sure to include both speed arrows of appropriate lengths **and** any force arrows you think are appropriate.

2 seconds

6 seconds

10 seconds

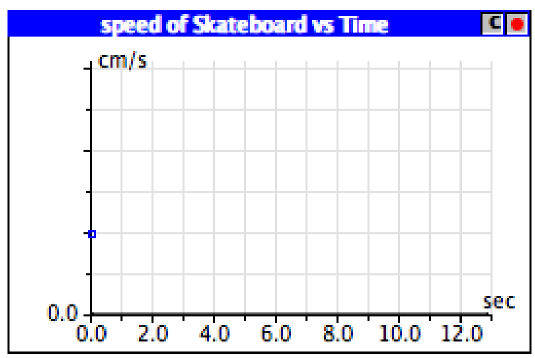
Briefly explain your force diagrams and how the speed arrows and force arrows (if any) you drew on all three diagrams correspond to your predicted speed-time and force-time graphs.

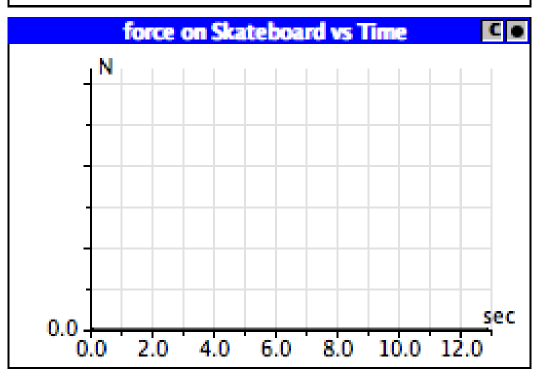
Collecting and Interpreting Evidence

Simulator Exploration. Now open the *I&M Simulator* set-up file for this homework assignment in your web-browser. (See the earlier handout for details on how to do this.) This set-up is very similar to those you have already seen in class; you can apply a force to the 'skateboarder' by holding down the spacebar on the keyboard.

Before running the simulator describe how you propose to use the spacebar to reproduce the pattern of forces you drew on your force-time graph.

Now run the simulator and apply the 'spacebar' force as you described above. Sketch the speed-time and force-time graphs produced by the simulator model.





Does the pattern of forces you applied in the simulator model produce a speed-time graph that agrees with your prediction? (Remember, only the shape of the graph is important.)

If not, return to the simulator and experiment to try and understand why this is. Explain any new ideas you may have.

Look back at the three force diagrams you drew for the skateboarder before using the simulator. Are the **force arrows** you drew consistent with the simulator model results? If not, describe how you would change the force arrows and why.

Looking at the same three force diagrams, are the lengths of the **speed arrows** you drew consistent with the speeds shown by the simulator speed-time graph? If not, describe how you would change the speed arrows and why.

Summarizing Questions

Answer these questions as part of the homework assignment. Be prepared to add any different ideas that may emerge during the whole class discussion.

S1: During which period(s) of time was mechanical energy being transferred **to** the skateboarder? (Before he interacted with the person pushing him, during the interaction, after the interaction, more than one, or all of these.) How do you know?

S2: During which period(s) of time was a force acting on the skateboarder in the same direction as his motion? (Before he interacted with the person pushing him, during the interaction, after the interaction, more than one, or all of these.) How do you know?

S3: Suppose you are watching an ice-hockey game. As the puck is sliding across the ice at a relatively constant speed, it passes close to a player, who hits it (with his stick) in the same direction as it is already moving. After the hit, you notice that the puck is moving much faster than it was before the hit. Use your ideas about forces to write a scientific explanation for why the puck's speed is greater after the hit than it was before.

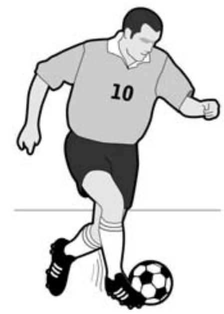
Explanation: Why was the puck moving faster after being hit?

Describe the Situation using a diagram: (Draw a force diagram for the puck during the interaction that made the speed change. Remember to include speed and force arrows and label them as you think appropriate.)

Write the narrative: (Use ideas about forces to connect the increase in speed to the force acting on the puck during the hit.)

LEPS	**Unit 2** LESSON 1: Interactions and Force

Purpose and Key Questions



When one object pushes or pulls on another object scientists say it is exerting a ***force***. For example, when a soccer player kicks a ball we say that the foot exerts a force on the ball. In this unit we will be investigating the effects that forces have on the motion of objects. We will start by examining how we can recognize when a force is acting on an object, and when it is not.

The key question for this lesson is:

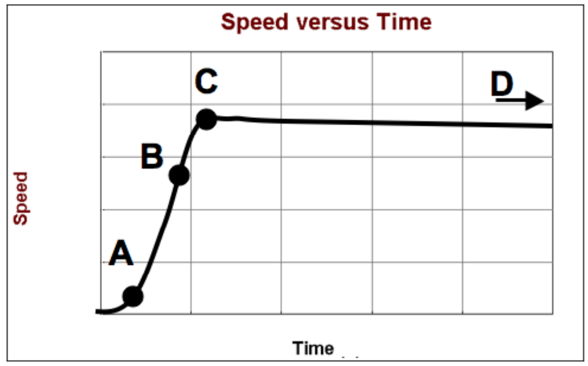
> ***When does the force of a quick push stop acting on an object?***

Predictions, Observations and Making Sense

<u>PART 1</u>. Think about a hockey player hitting a stationary puck. Because of his interaction with it, the ball starts to move, and slides across the ice

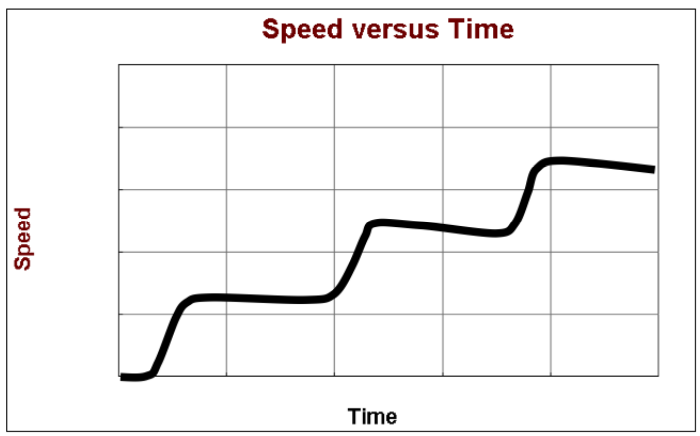
A speed-time graph for the hockey puck is shown on the next page. Discuss with your neighbors over what period on the graph you think the force caused by the stick is acting on the puck. Which labeled point on the graph is closest to your idea about when the force of the stick stops acting on the puck? Explain why you chose that particular point.

CQ 1-1: Which point on the graph is closest to where you think the force of the stick stopped acting on the puck?



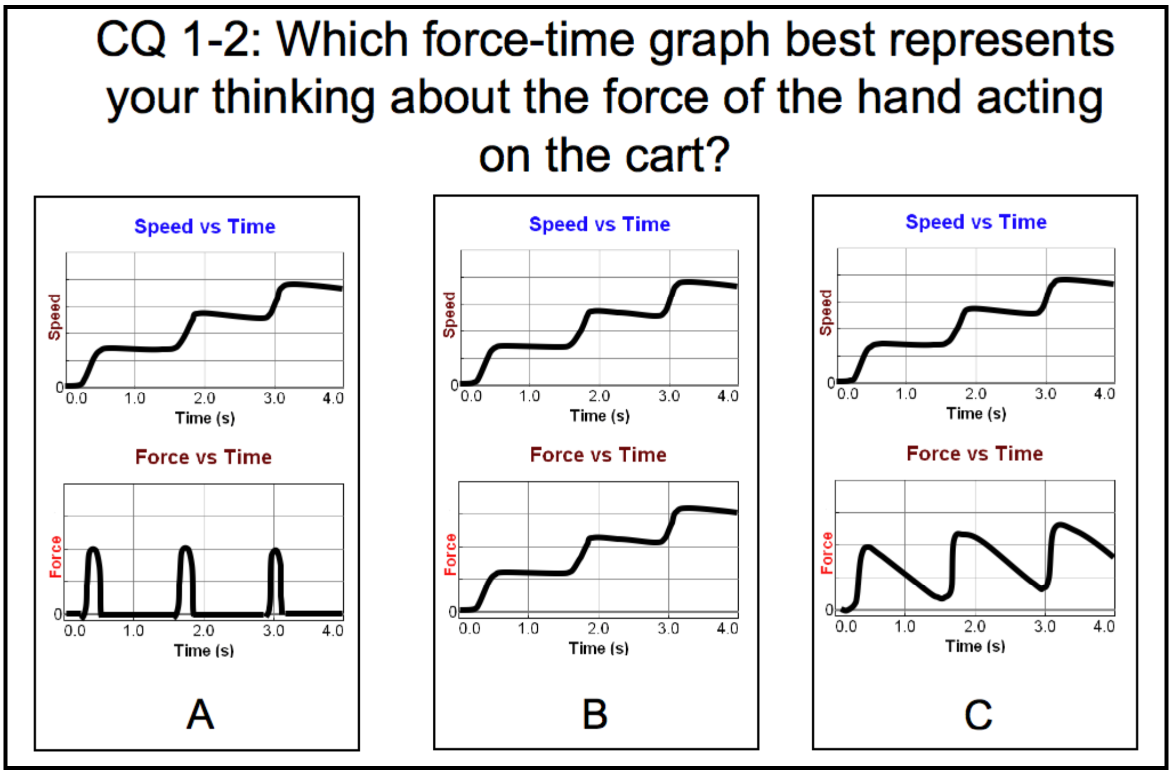
A. Point A
B. Point B
C. Point C
D. Not until the puck stops

PART 2. Your instructor will show you an experiment involving a low-friction cart on a track. The cart will be given a gentle push to start it moving and then, while it is moving along the track, it will be given some more quick taps in the same direction as its motion. Its speed time graph. Measured with a motion sensor, should look similar to this.



Highlight the sections of the speed-time graph in which you think the hand was in contact with the cart. Why did you choose these sections?

When do you think the force caused by the hand is acting on the cart in this demonstration? Is it acting the whole time the cart is moving, or only during certain periods? Suppose you could measure the strength of this force while the cart is moving, which of the force-time graphs shown below best represents your thinking? Discuss this question with you neighbors and record your reasoning below.



Your instructor will show you an experiment in which the strength of the force applied to the cart by the hand is measured.

Which of the options in the question above most closely corresponds to the data recorded in the experiment?

PART 3. Now discuss the following questions with your neighbors. Remember to base your answers on the evidence from PART 2.

What happened to the speed of the cart while the hand was interacting with it? Did it increase quickly, decrease quickly, or remain reasonably constant? Why do you think this was?

Did the hand exert a force on the cart while it was interacting with it? How do you know?

What happened to the speed of the cart during the periods in between the pushes? Did it increase quickly, decrease quickly, or remain reasonably constant? Why do you think this was?

Did the force caused by the hand continue acting on the cart after it had lost contact? Again, how do you know?

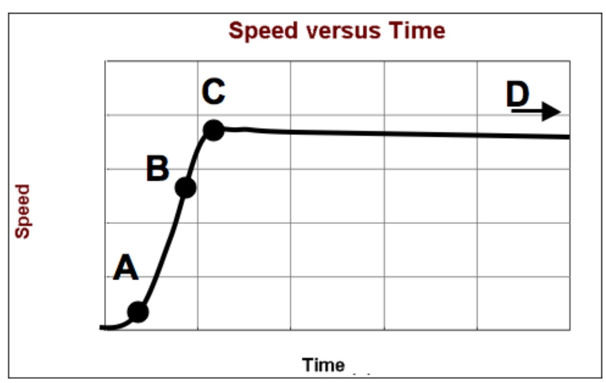
Summarizing Questions

1. Do you think the force of the hand was transferred from the hand to the cart during the push, and then continued to act on it after contact was lost? What evidence supports your thinking?

2. At what moment do you think the force of the hand ceased to act on the cart? Explain your thinking!

3. The question below was asked previously at the beginning of this activity. What would be your response now? If your thinking has changed, make a note of your reasoning below the question.

CQ 1-3: Now which point on the graph is closest to where you think the force of the stick stopped acting on the puck?



A. Point A
B. Point B
C. Point C
D. Not until the puck stops

4. The key question for this activity was:

When does the force of a quick push stop acting on an object?

Make sure you can answer this question using ideas that are supported by evidence from this activity.

Slide 1 - Slide 1

LEPS

U2L01HW

Select either option below and then click "Continue" to start the homework.

- (●) A) Sure.
- ( ) B) Sounds good.

Review Area
(304 x 65)
(X:476; Y:435)
You must answer the question before continuing

Continue

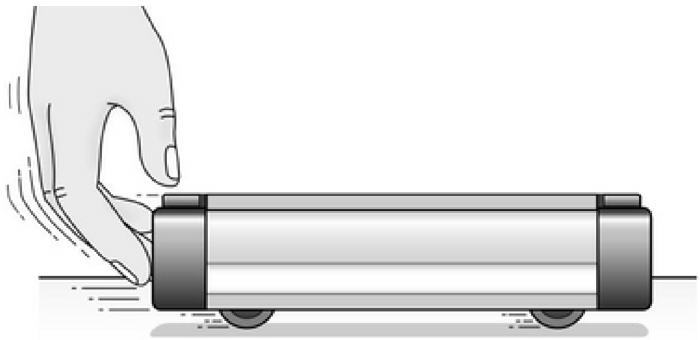
Slide 2 - Introduction

LEPS

U2L01HW

Introduction

Pushes, such as those used in the demonstrations you have seen, are examples of forces. Whenever one object is pushing or pulling on another object, we say it is exerting a force on the other object. Notice that this means the pushes and pulls you saw in Unit 1 when considering contact push/pull interactions could also be described in terms of forces exerted on the cart by a person or another cart.



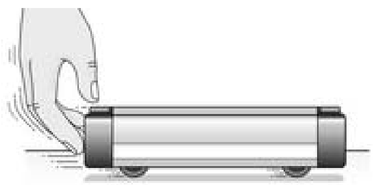
Just as with the energy description of contact push/pull interactions you saw in Unit 1, we can also draw a diagram to help us analyze and explain the force description of the same interactions. In this homework activity you will be introduced to such 'force' diagrams.

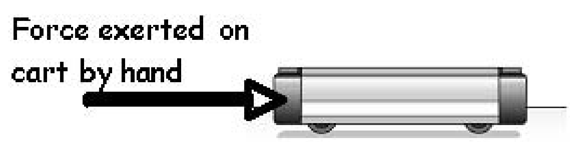
Back Continue

Slide 3 - Force diagrams - pushing

Force Diagrams - Pushing a cart

In a force diagram, we identify the object of interest and all the forces (pushes and pulls) being exerted on it by **other** objects at a **particular moment in time**. We represent these forces with 'force arrows' drawn on the diagram, which are labeled to show what they represent. For example, the force of your hand pushing the cart would be represented like this:





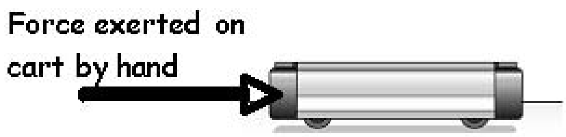
Notice that the force diagram shows only one of the objects involved in the interaction (the cart), and that the other object involved (the hand) is only mentioned in the labeling of the arrow representing the force it is exerting.

Back Continue

Slide 4 - Slide 4

Force Diagrams - Pushing a cart

It would be useful if our force diagrams gave us some information about how strong the forces acting on an object are and in which direction they act. As shown on the previous page, a gentle shove to the right could be represented by this force diagram.



Now suppose you gave the same cart a harder push back along the track in the opposite direction. Which of the force diagrams do you think conveys the information that the second push was both harder than before and in the opposite direction?

A

B

C

Click on the entity of your choice. You may select more than one answer. To remove a single selection, click on the marker again. To remove all selections, click the clear button.

Review Area
You must answer the question before continuing

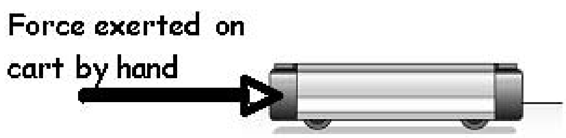
Clear | Skip | Back | Continue

Help

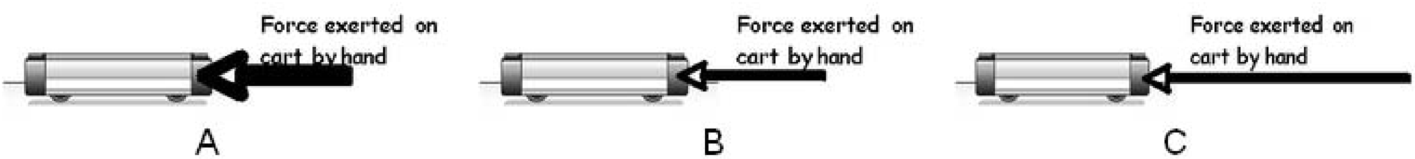
Slide 5 - Slide 5

Force Diagrams - Pushing a cart

It would be useful if our force diagrams gave us some information about how strong the forces acting on an object are and in which direction they act. As shown on the previous page, a gentle shove to the right could be represented by this force diagram.



Now suppose you gave the same cart a harder push back along the track in the opposite direction. Which of the force diagrams do you think conveys the information that the second push was both harder than before and in the opposite direction?



Feedback: Choices A or C would both be appropriate, since increasing the length or thickness of the arrow would both be reasonable ways to show that the force is stronger. However, because it easier to draw, we will choose to represent the relative strength of forces using arrows of different length rather than different thicknesses.

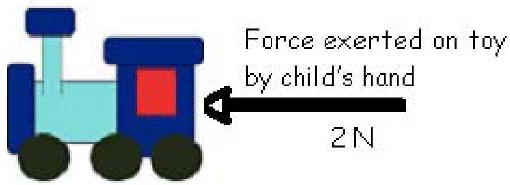
Back Continue

Slide 6 - Units of force

Force Diagrams - Units of force

The strength of a force is measured in units of newtons (N), named in honor of Sir Isaac Newton, a famous English scientist you will learn more about later on. It would take a force with a strength of about one newton to lift up a 4-pack of AA batteries.

Sometimes it is useful to add information on the strength of a force to a force diagram. For example, if a child pushes on a toy train (with their hand) with a force strength of 2 N, that would be represented by the diagram below.



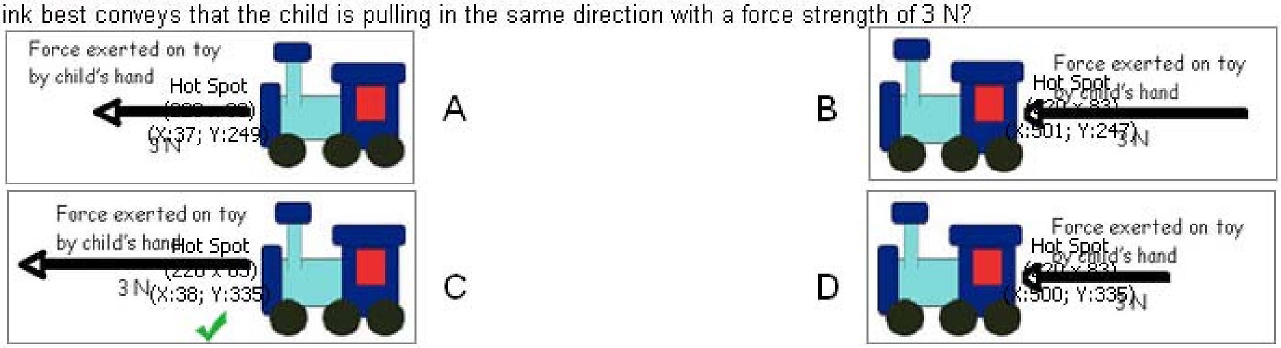
Back Continue

Slide 7 - Force diagrams - pulling

Force Diagrams - Pulling

Instead of pushing, another way to exert a force on an object is to pull on it.

If the diagram shown above represents the child pushing the toy train to the left with a force of 2 N, which of the diagrams do you think best conveys that the child is pulling in the same direction with a force strength of 3 N?



Click on the entity of your choice. You may select more than one answer. To remove a single selection, click on the marker again. To remove all selections, click the clear button.

Review Area
You must answer the question before continuing

Help

Clear Skip Back Continue

Slide 8 - Slide 8

Force Diagrams - Pulling

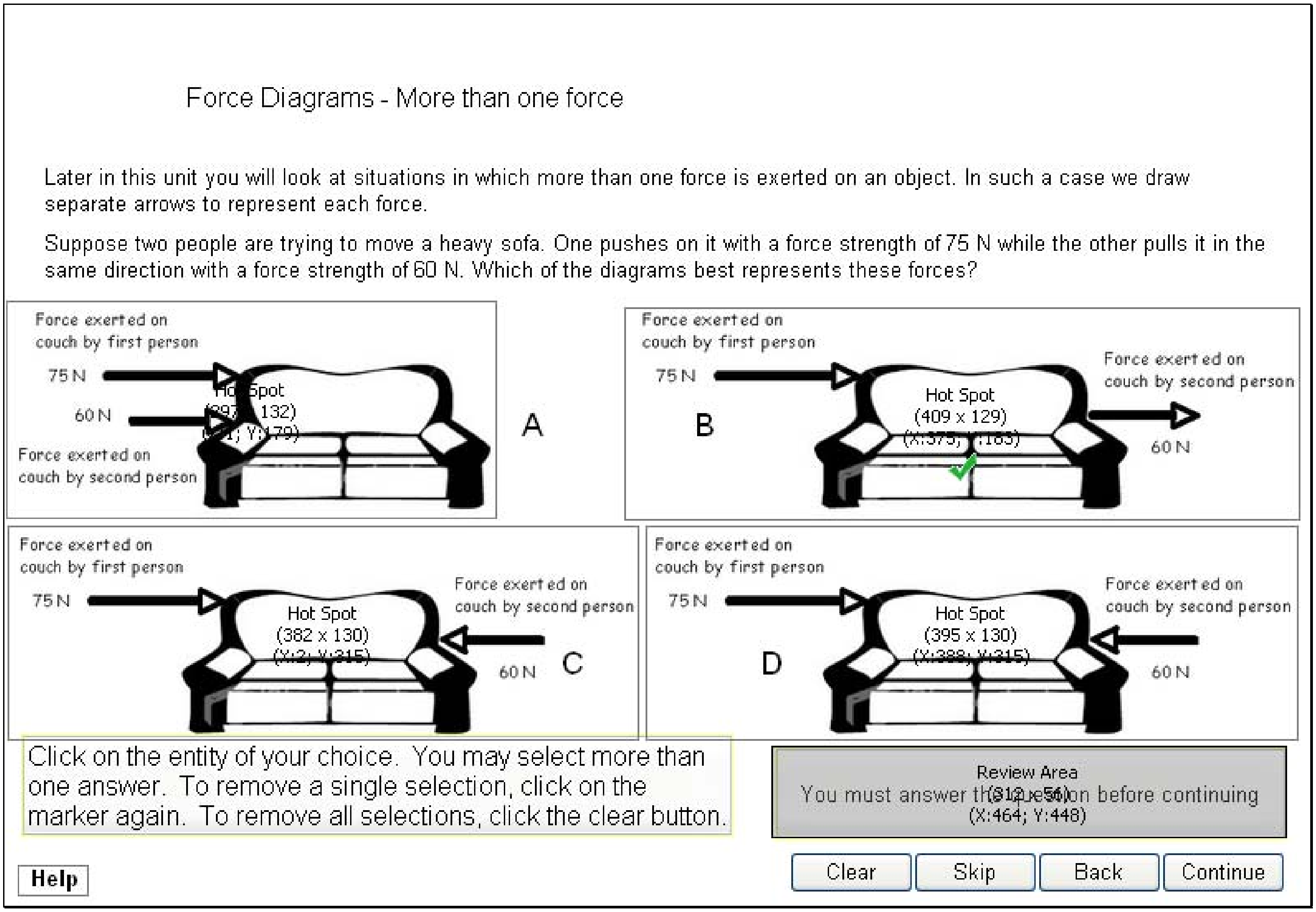
Instead of pushing, another way to exert a force on an object is to pull on it.

If the diagram shown above represents the child pushing the toy train to the left with a force of 2 N, which of the diagrams do you think best conveys that the child is pulling in the same direction with a force strength of 3 N?

Feedback: Choices B and C both show a longer arrow, representing a stronger force being exerted in the same direction, and as you saw in Unit 1, a push and a pull of the same strength have the same effect on the motion of an object. However, we will always draw force arrows on the side of the object from which the force is applied. Hence, a push will always be represented by a force arrow pointing toward the object, and a pull will always be represented by an arrow pointing away from the object. With this in mind, choice C is the most appropriate.

Back | Continue

Slide 9 - More than one force

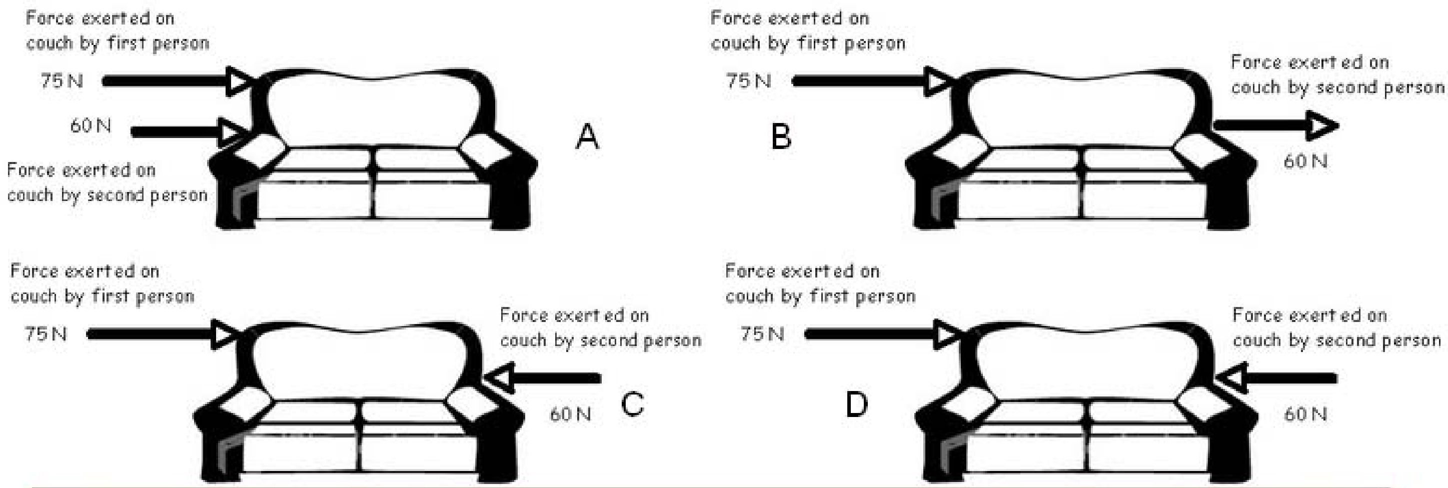


Slide 10 - Slide 10

Force Diagrams - More than one force

Later in this unit you will look at situations in which more than one force is exerted on an object. In such a case we draw separate arrows to represent each force.

Suppose two people are trying to move a heavy sofa. One pushes on it with a force strength of 75 N while the other pulls it in the same direction with a force strength of 60 N. Which of the diagrams best represents these forces?



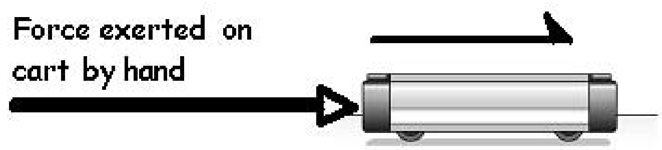
Feedback: Choice B is most appropriate for this situation since it shows a push and a pull of appropriate strengths both acting in the same direction.

Back Continue

Slide 11 - Force and motion

Force Diagrams - Diagrams for objects in motion

Finally, if the object is moving at the moment in time for which we are drawing the force diagram, then it is important to know in which direction. When this is the case, we can show this by drawing a speed arrow above the object. We use a half-arrow (just like the speed arrow you saw in the *I&M Simulator* in Unit 1) so as not to confuse it with the force arrows, since it represents the speed of the cart, **not** a force acting on the cart. For example, when the moving cart is given a push in the same direction as its motion, the force diagram looks like this:



Note that the speed arrow only tells about the speed of the object at the particular moment in time for which the force diagram is being drawn. It does not tell anything about whether the object's speed is in the process of changing, or whether it is remaining constant.

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Slide 12 - Quiz

Quiz - Introduction

You should answer the following questions based on what you learned during this homework activity. Report your answers separately according to the instructions given you by your instructor. Keep this homework open in a separate browser window until you finish answering all the questions.

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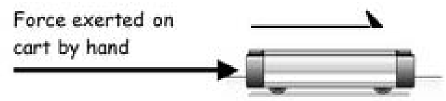
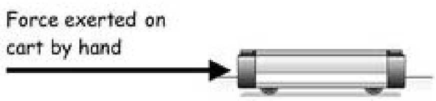
Slide 13 - Slide 13

Quiz - Question 1

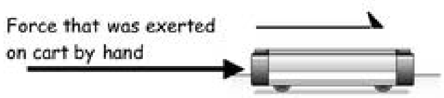
A moving cart is given a push by someone's hand so that a force is exerted on it. The force diagram for a moment in time while this force is acting is shown here. Several seconds later it is observed that the cart is still moving, but measurements show that the force of the hand is no longer acting on the cart. Which of the force diagrams below would be most appropriate for the cart at this later moment in time?



A)



B)



C)

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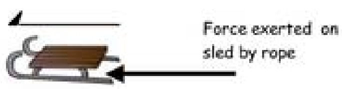
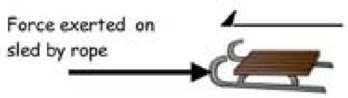
Slide 14 - Slide 14

Quiz - Question 2

A child's sled is sliding across a frozen lake toward a patch of thin ice. To try and prevent this, you lasso the sled and pull on the rope in the opposite direction to its motion to try and slow it down.

Which of the diagrams below would best represent this situation, assuming it is for a moment in time before you successfully brought the sled to a stop?

A) 

B) 

C) 

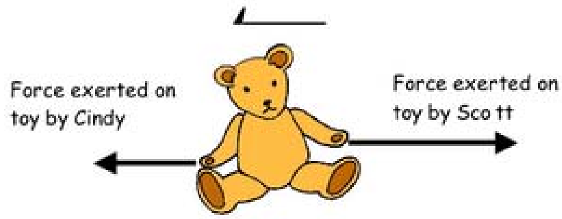
D) 

Back Continue

Slide 15 - Slide 15

Quiz - Question 3

While arguing over who owns a toy, two children, Cindy and Scott, both grab it and engage in a 'tug-of-war' over it. At one certain moment in time during their struggle, the force diagram for the toy looks like this.



Which of the following statements best describes what this force diagram represents?

A) Scott is pulling harder than Cindy, and the toy is moving toward him at this particular moment in time.

B) Cindy is pulling harder than Scott, and the toy is moving toward her at this particular moment in time.

C) Cindy is not pulling as hard as Scott, but the toy is moving toward her at this particular moment in time.

D) At this particular moment in time Scott and Cindy are pulling equally hard, so the toy is not moving.

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Slide 16 - Conclusion

Force Diagrams - Conclusion

In Unit 2 you are developing ideas about how the motion of an object is related to the forces being exerted on it. Therefore, force diagrams are useful tools since they allow you to represent the forces acting on an object and its motion at the same time. As you progress through Unit 2, you will see many force diagrams, as well as draw some of your own.

At this early stage in the unit, you may still be developing your ideas about what a force is and how to recognize when a force is being exerted on an object. However, you can still use force diagrams to represent your thinking and quickly compare your ideas with other students.

You can download and keep a document that summarizes the ideas about force diagrams you have seen in this homework assignment.

Summary

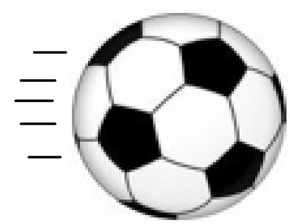
Back Continue

LEPS	Unit 2 LESSON 2: Motion and Force

Purpose and Key Questions

In the first lesson of this unit you thought about the force exerted on an object during a quick push. However, when such a quick push is used to start an object moving, is there still a force pushing the object forward after the initial push is over? This is the question you will consider in this lesson.

For example, **after** you kick a soccer ball, the ball continues to move. Does this continued motion mean that there is still a force pushing the ball forward or is it possible for the ball to keep moving forward without a force pushing it in that direction?



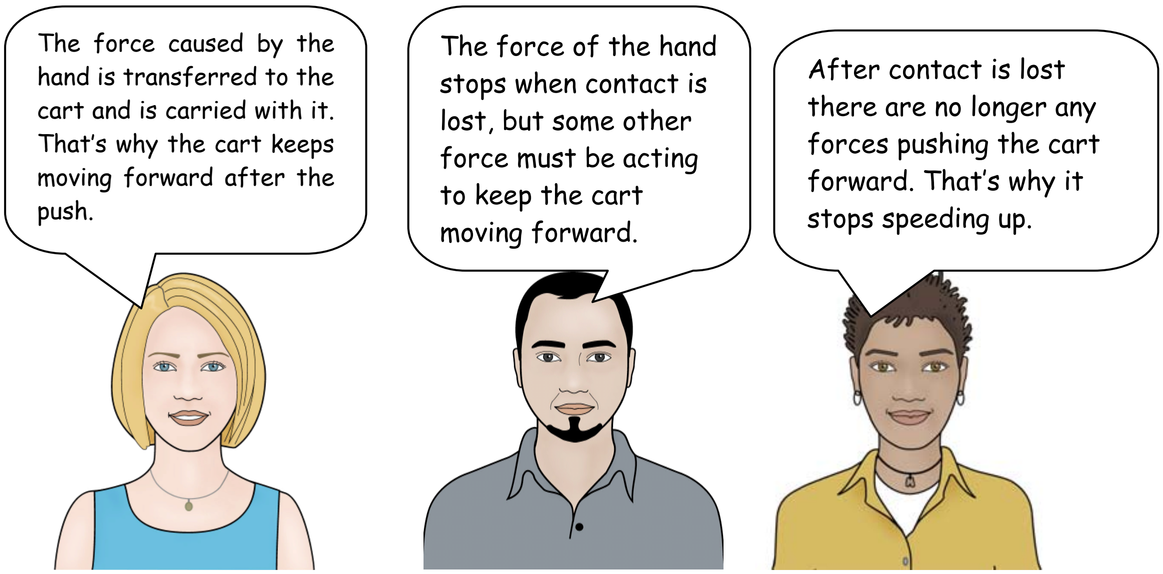
The key question for this lesson is:

> ***When an object is moving, does this mean there must be a force pushing it in the direction of its motion?***

Predictions, Observations and Making Sense

PART 1. Think about giving a low friction cart a quick push on a level track so that it keeps rolling along the track after your push.

Three students are discussing the motion of the cart and the force acting on it. They all agree that while the hand is pushing the cart there is a force acting on it, but have different ideas about whether a force is still pushing the car forward after the hand has lost contact with it.



Samantha Victor Amara

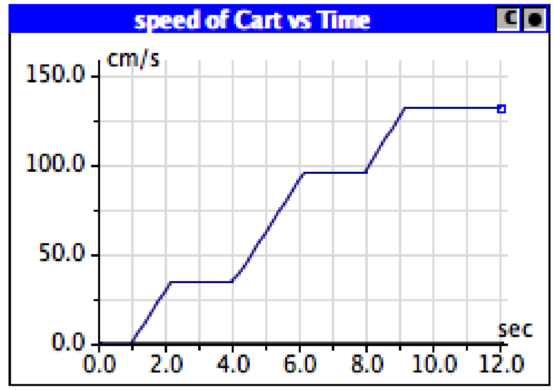
Discuss the students' ideas with you neighbors, decide who you agree with (if any) and note your reasoning below the question. Then participate in the class vote and discussion.

CQ 2-1: In the discussion between three students about the force acting on the cart after the quick push, whom do you agree with?

a. Samantha
b. Victor
c. Amara
d. None of them

<u>PART 2.</u> In this lesson we will use the *I&M Simulator* to compare your thinking to that of scientists.

On the right is a speed-time graph taken from an *I&M Simulator* set-up that models the demonstration from Lesson 1 in which you saw a cart being given two or three successive pushes. (Note: the effects of friction are ignored in this setup.)



Indicate the periods on the speed-time graph when you think the cart in the simulator was actually being pushed forward by someone's hand. How do you know?

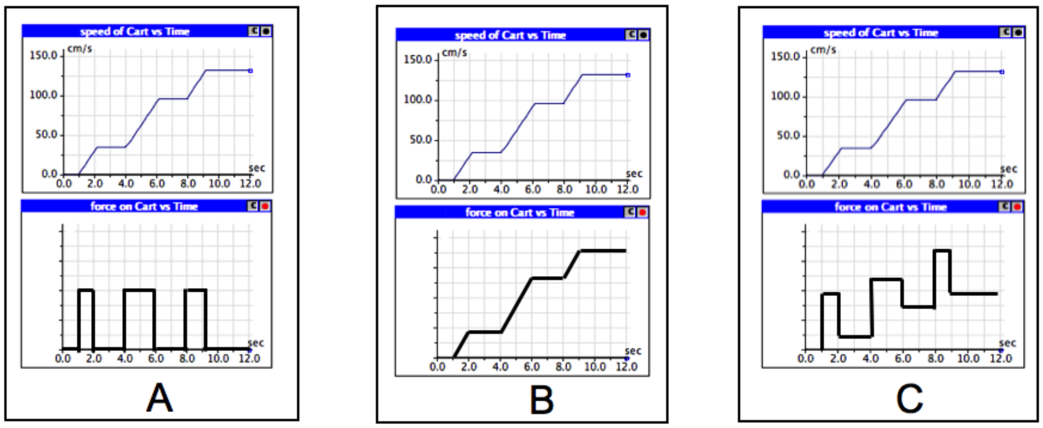
In between your marked sections, do you think there is still a force pushing the cart forward? Why do you think so?

The *I&M Simulator* can also 'measure' **<u>ALL</u>** the forward forces acting on the cart in the simulator model. It does this by displaying a force-time graph that shows the strength of any and all forces pushing the cart forward as it moves. (During any period when there is a force acting on the cart, the graph will show a non-zero value. During any period when there is no force acting, the graph will show a force strength of zero.)

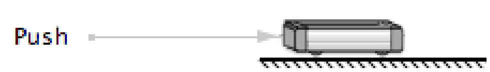
On the next page are three suggestions for what the force-time graph for the cart would look like as the cart moves along the track, producing the speed-time graph shown above.

Discuss these force-time graphs your neighbors, decide which one best represents your thinking, and note your reasoning below the question. Then participate in the class vote and discussion.

CQ 2-2: Which force-time graph best represents your thinking about the force pushing the cart forward as it moves along the track?



Your instructor will now run the *I&M Simulator*, to compare the class' ideas with those scientists' ideas upon which the simulator model is based.



While the simulator is running the cart will be given some shoves (by pressing on the spacebar of the computer keyboard). Each shove will continue (at a constant strength) as long as the spacebar is held down.

Which of the force-time graphs in CQ 2-2 (above) looks most like the simulator result?

PART 3. Now discuss and answer the following questions with your neighbors. Remember to base your reasoning on the evidence you have seen.

During the periods when the simulator cart was being given a shove was there a force pushing it forward? What evidence from the simulator graphs supports your idea?

What action in the real world do these simulator shoves correspond to?

During the periods in between these simulated shoves, was a force pushing the cart forward? Again, what evidence from the graphs supports your idea?

Summarizing Questions

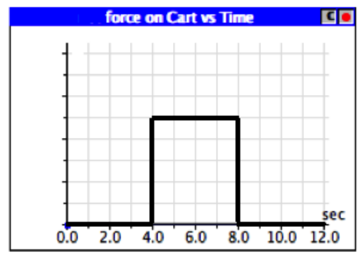
1. While the simulator cart was moving along the track was there a force pushing it forward the whole time or only at certain times? What evidence supports your answer?

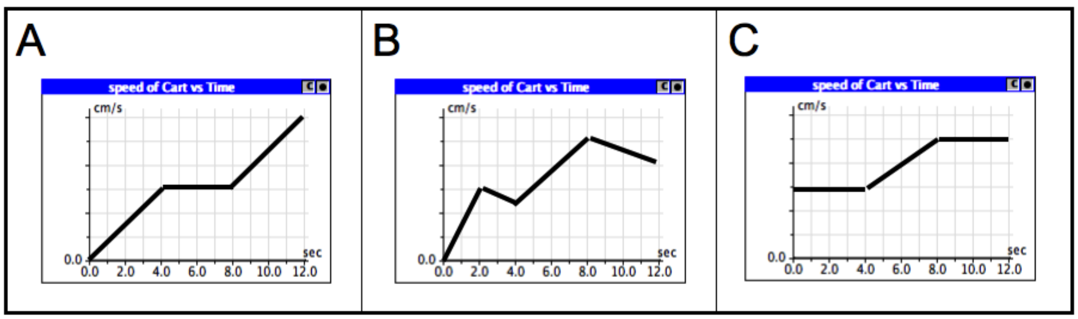
2. During a contact push/pull interaction, what do you think is transferred from the source to the receiver: energy, force, both, or neither? Explain your reasoning.

3. During the periods while the simulator cart was being given a shove its speed was increasing. In between these periods its speed remained constant. Why do you think there is this difference

4. Which of the speed-time graphs in the question below would be produced by the given force-time graph?

CQ 2-3: Suppose the force time graph for a simulator cart looked like this. Which of the speed-time graphs below could be produced by applying a single force in this way?





5. The key question for this lesson is:

When an object is moving, does this mean there must be a force pushing it in the direction of its motion?

Make sure you can answer this question using ideas that are supported by evidence from this activity.

Slide 1 - Slide 1

LEPS

U2L02HW

Select either option below and then click "Continue" to begin the homework.

- (•) A) OK.
- ( ) B) Sounds good.

You must answer the question before continuing

Continue

Slide 2 - Introduction

LEPS

U2L02HW

Relating Ideas About Force and Energy - Introduction

In Unit 1, you developed ideas to explain the behavior of objects during contact push/pull interactions in terms of a transfer of mechanical energy from one interacting object to the other. In Unit 2, you are developing ideas that will help explain the same interactions in terms of the force that one of the interacting objects exerts on the other.

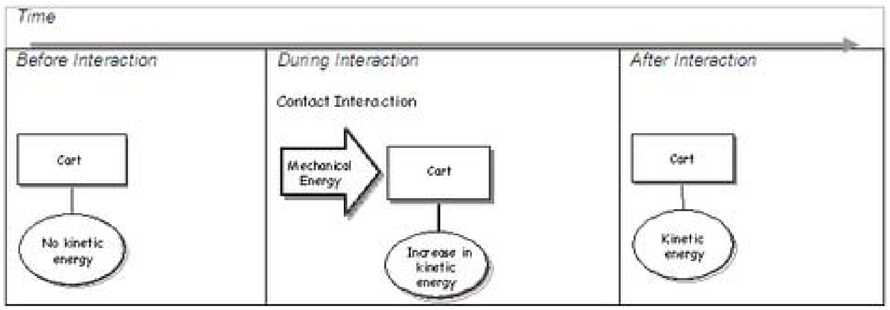
This homework activity will help you begin to think about how these two different ways of thinking about contact push/pull interactions are related to each other. You will also consider how students' prior knowledge (ideas they bring into the classroom with them that are based on earlier experiences) can affect how they interpret new information and thereby affect their learning.

Continue

Slide 3 - Relating force and energy - pushing

Relating Ideas About Force and Energy - Pushing a cart

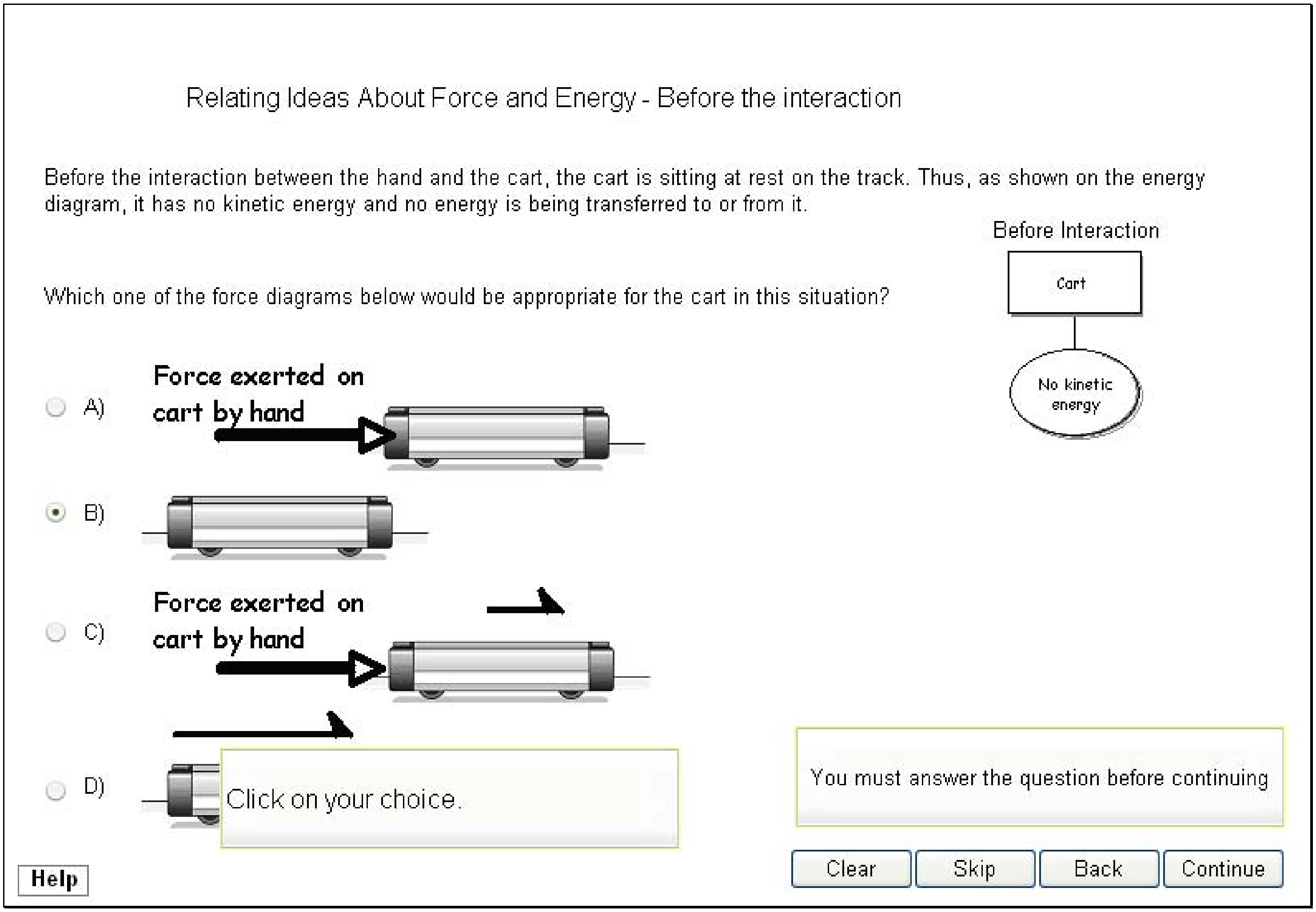
Consider the situation of a stationary, low-friction cart that is given a quick shove with a hand to start it moving. Below is a timeline of I/O energy diagrams that show how the energy transfer to the cart and the changes in its kinetic energy are related to the interaction.



On the following pages, you will select force diagrams that correspond to these I/O energy diagrams.

Back Continue

Slide 4 - Force and energy - Before an interaction

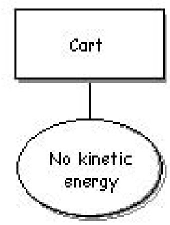


Slide 5 - Slide 5

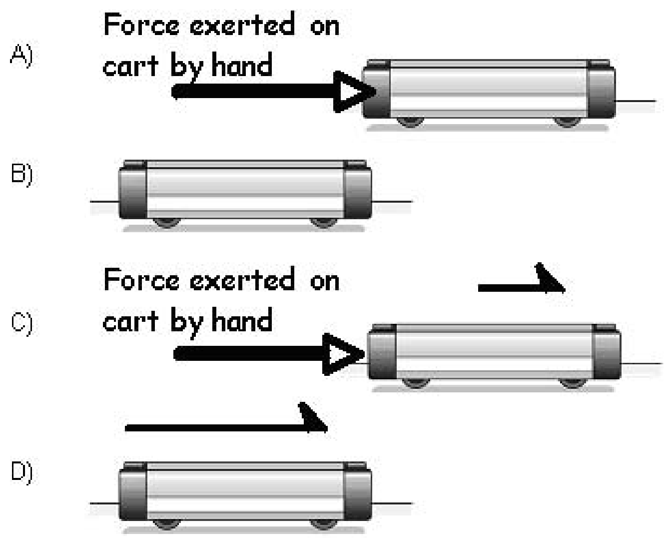
Relating Ideas About Force and Energy - Before the interaction

Before the interaction between the hand and the cart, the cart is sitting at rest on the track. Thus, as shown on the energy diagram, it has no kinetic energy and no energy is being transferred to or from it.

Before Interaction



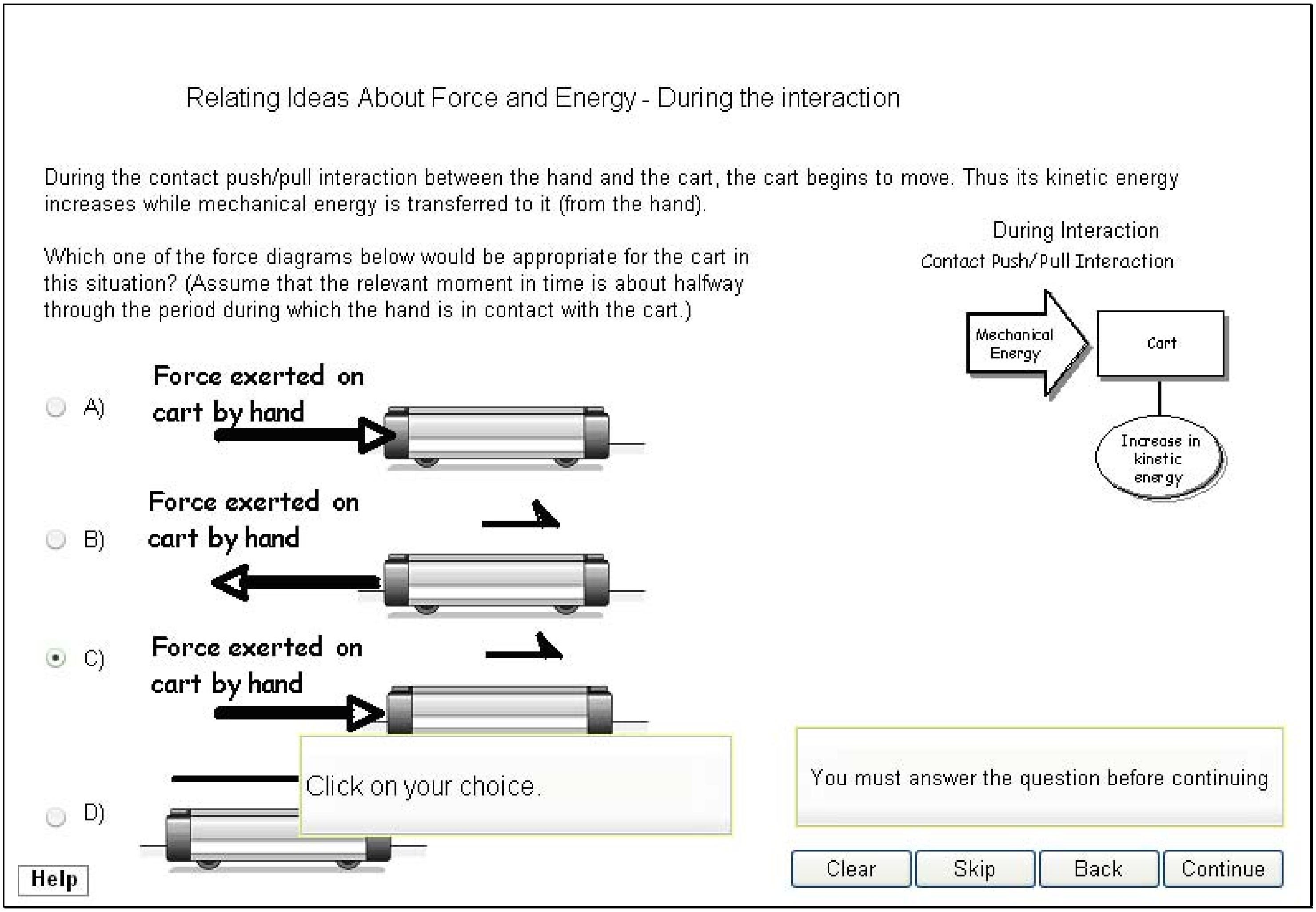
Which one of the force diagrams below would be appropriate for the cart in this situation?



Feedback: Choice B is the only appropriate one. Since the cart is at rest, the diagram should not have a speed arrow, and since it is not yet being pushed in any way, it should not have a force arrow either.

Back | Continue

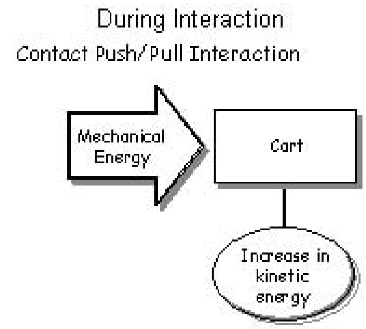
Slide 6 - Force and energy - During an interaction



Slide 7 - Slide 7

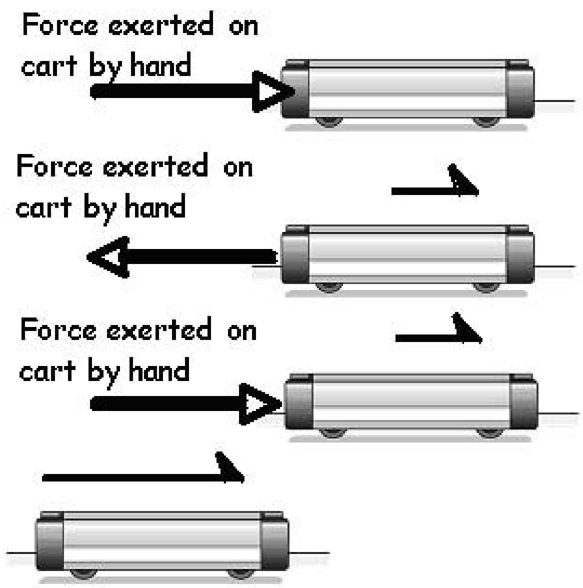
Relating Ideas About Force and Energy - During the interaction

During the contact push/pull interaction between the hand and the cart, the cart begins to move. Thus its kinetic energy increases while mechanical energy is transferred to it (from the hand).



Which one of the force diagrams below would be appropriate for the cart in this situation? (Assume that the relevant moment in time is about halfway through the period during which the hand is in contact with the cart.)

A) B) C) D)



Feedback: In this case, Choice C is the only appropriate one. Since the hand is in contact with the cart at this point, it must be exerting a force on it. Further, since this is for a moment in time about halfway through the period of contact, the cart will already have started moving, so the diagram should have a short speed arrow. Finally, the cart would be moving in the same direction as the force exerted by the hand.

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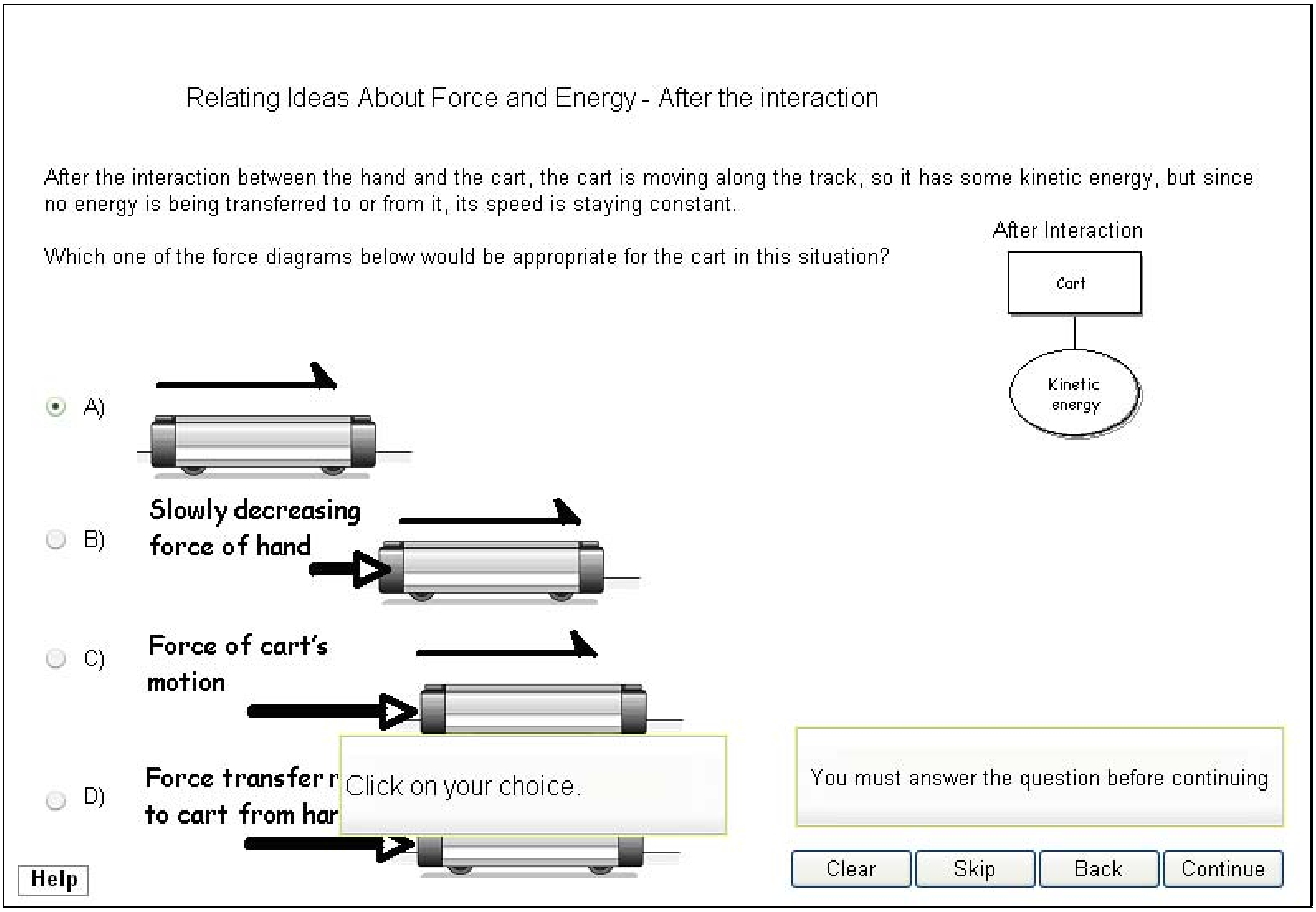
Slide 8 - Force and energy - After an interaction

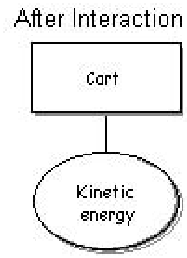


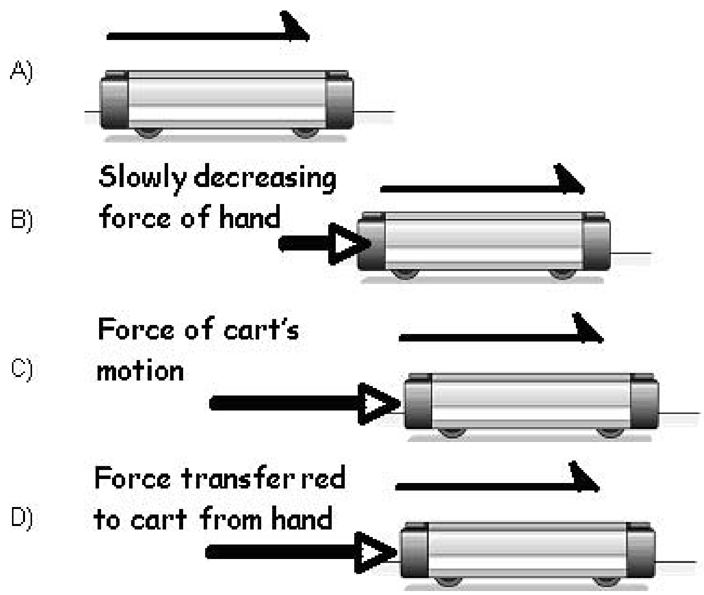
Slide 9 - Slide 9

Relating Ideas About Force and Energy - After the interaction

After the interaction between the hand and the cart, the cart is moving along the track, so it has some kinetic energy, but since no energy is being transferred to or from it, its speed is staying constant.

Which one of the force diagrams below would be appropriate for the cart in this situation?





Feedback: Choice A is the only appropriate one in this case. You saw in Lesson 2 that after the hand has lost contact with the cart, there are no longer any forces pushing it forward. That's why it stops speeding up at this point.

Back Continue

Slide 10 - Quiz

Quiz - Introduction

You should answer the following questions based on what you learned during this homework activity. Report your answers separately according to the instructions given you by your instructor. Keep this homework open in a separate browser window until you finish answering all the questions.

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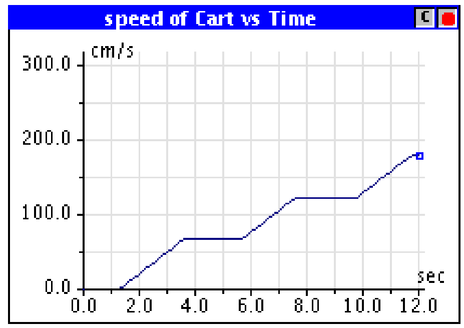
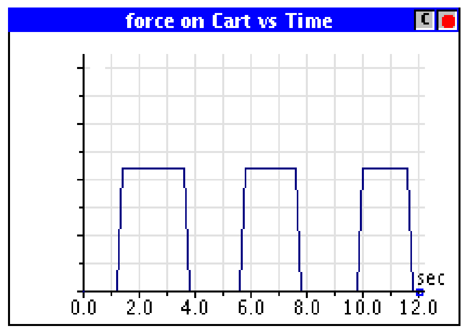
Slide 11 - Slide 11

Quiz - Question 1

Shown to the right are the speed-time and force-time graphs from a simulator.





Which of these statements is consistent with what the graphs show is happening to the simulator cart at t = 9 seconds?

A) Its kinetic energy is increasing and no force is acting on it.

B) Its kinetic energy is constant and no force is acting on it.

C) Its kinetic energy is increasing and a force is acting on it.

D) Its kinetic energy is decreasing and a force is acting on it.

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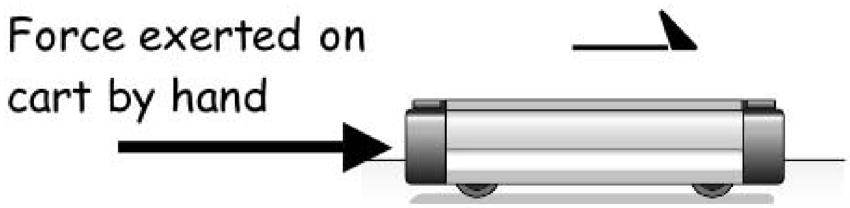
Slide 12 - Slide 12

Quiz - Question 2

Here is a force diagram for a cart at a particular moment in time.



Assuming the same force continues to act, how will this cart's kinetic energy in a few seconds compare with its kinetic energy now, and why?

A) Its kinetic energy will be the same because the force stays the same.

B) It will have less kinetic energy because the force will slow it down.

C) Its kinetic energy will be the same because no energy is being transferred to it.

D) It will have more kinetic energy because energy is being transferred to it.

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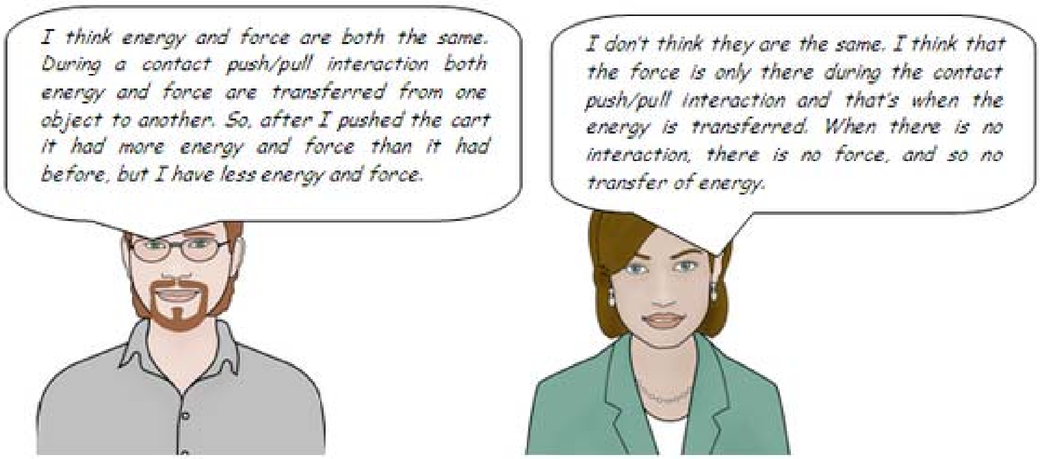
Slide 13 - Slide 13

Quiz - Question 3

Two students, Dave and Luisa, are discussing their ideas about how energy and force ideas are related to each other.



Dave Luisa

Which student's thinking does the evidence you have seen so far support?

A) Dave

B) Luisa

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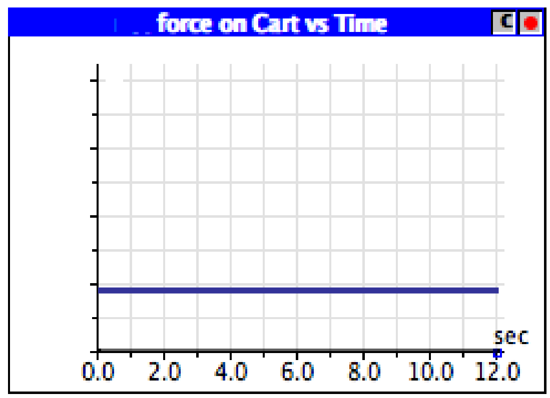
LEPS	Unit 2 LESSON 3: Motion with a Continuous Force

Purpose and Key Questions

In Lesson 1 you saw the effect that quick pushes had on the motion of a cart. This is like the situation in many sports, where the players move the ball (or puck) around using quick pushes of their hands, feet, or a bat/racket of some kind. Scientists call such quick pushes **impulsive** forces.

But what would the motion of an object be like if a single **continuous, constant**, force acted on an object? By this we mean a force that continues to act over a long time period and whose strength stays constant over that period. Thus the force-time graph would like that shown to the right.



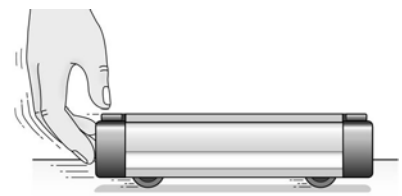
For example, suppose your friend was standing balanced on a skateboard and you pushed, and kept on pushing, with the same strength force, in the same direction. What would his motion be like?

The key question for this lesson is:

> ***How does an object move when a force of constant strength continuously pushes it forward?***

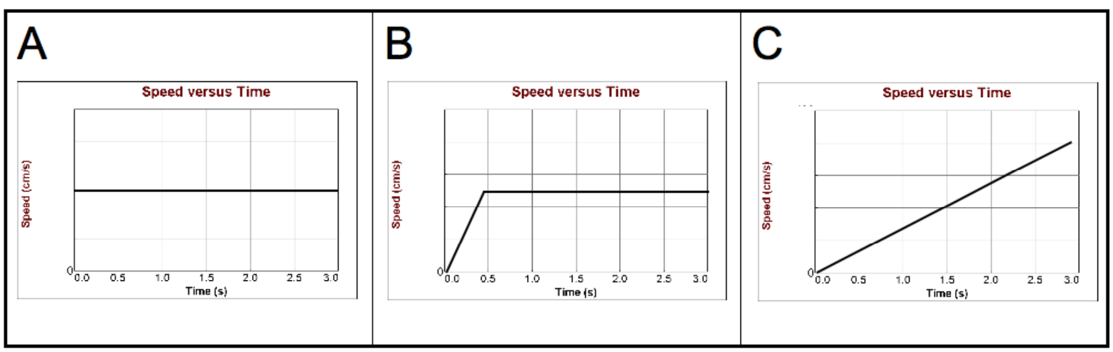
Predictions, Observations and Making Sense

PART 1: Imagine you had a low-friction cart at rest, at one end of a track. Now, suppose you were to interact with the cart by pushing it continuously from behind with a **constant strength push.** What do you think its motion would be like?



Discuss your thinking with your neighbors, and decide which of the graphs in the question below best represents your thinking. Make a note of your reasoning below the question and then participate in the class vote and discussion.

CQ 3-1: Which of the following speed-time graphs do you think would be closest to that for the cart if it were pushed along the track by a continuous, constant, force?



PART 2. In order to test your thinking we will need to find a way to apply a continuous, constant, force to a cart. We will first try doing this by pushing manually, as we have before.

You instructor will show you an experiment in which a person tries to use their hand to push a low-friction cart along a track using a continuous, constant, force. The strength of the force the person is exerting on the cart will be measured using a force probe attached to the cart and the results will be displayed on a force-time graph.

According to the force-time graph was the force exerted on the cart continuous and constant? How can you tell?

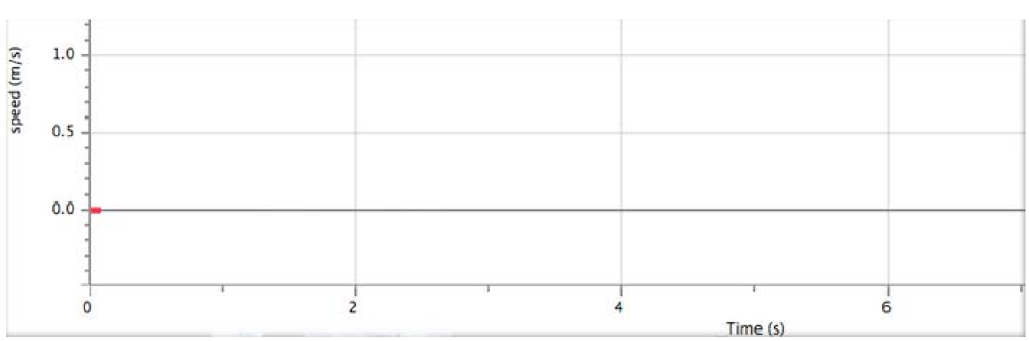
In reality, most people find it very difficult to maintain a continuous push of a constant strength. We will now check to see if there is a better way to arrange for such a force to act on the cart.

You instructor will show you a demonstration of a low-friction cart with a fan unit mounted on it. While the fan is running the cart will push against the force probe, which will be held steady in front of it.

Do you think the fan unit exerts a continuous, constant, force on the cart while it is running? What evidence supports your thinking??

<u>PART 3.</u> Now that we have a way to apply a continuous, constant, force to the cart, we can check how it moves to when only this force is acting on it. Your instructor will show an experiment in which a cart starts at rest and is pushed along a track by a fan unit. The speed-time graph of the cart will be displayed.

Sketch the speed-time graph for the motion of the cart.



Discuss with your neighbors. What was happening to the speed of the cart while the fan unit was pushing it along the track? Does this confirm or refute your prediction from PART 1?

Suppose this demonstration were repeated using three tracks joined end-to-end. Do you think the fan-cart would continue to speed up in this case, or do you think something else would happen?

Discuss your thinking with your neighbors, and decide which of the responses in the question below best represents your thinking. Make a note of your reasoning below the question and then participate in the class vote and discussion.

CQ 3-2: If the fan-cart were started from rest and allowed to run along three tracks laid end-to-end, what do you think would happen?

A. Its speed would increase along the first track but become constant soon after that.

B. It would continue speeding up all the way along the three tracks.

C. It would speed up at first and then begin to slow down.

Your instructor will now show you a movie of the experiment being performed. The movie will be paused at the relevant points so that its time code can be used to estimate how long it takes the cart to travel the length of each of the three tracks.

Record how long it takes for the fan-cart to travel down each of the three tracks,

First track:

Second track:

Third track:

Discuss with your neighbors. What happens to the speed of the cart as it travels down the three tracks? Which of the responses to CQ 3-2 does the evidence from the movie support? Explain how you know?

Summarizing Questions

1. If a cart is at rest and a force acts on it, what happens? If the same force continues to act on the cart what happens to the cart's speed?

2. In the previous lesson you saw that just because an object is moving this does not necessarily mean that a force is pushing it forward. So, what evidence would you look for to tell you that there is definitely a force pushing it forward? Explain your reasoning below the question.

CQ 3-3: Which of the following would be **definite evidence** that a force is pushing an object forwards?

A. Motion with decreasing speed only
B. Motion with increasing speed only
C. Motion with constant speed only
D. Any motion, regardless of how the speed is behaving

3. Suppose the fan blade jammed (and so suddenly stopped rotating) as the fan-cart was moving along the track? What would happen to the motion of the cart? Briefly explain your thinking.

CQ 3-4: Which of the following do you think would happen if the fan blade jammed as it was pushing the cart along the track?

A. It would continue speeding up until it reached the end of the track
B. It would stop speeding up immediately
C. It would continue to speed up for a short time

4. The key question for this activity was:

How does an object move when a force of constant strength continuously pushes it forward?

Make sure you can answer this question using ideas that are supported by evidence from this activity.

Slide 1 - Slide 1

LEPS

U2L03HW

Select either option below to start the homework.

- A) I'll do that.
- B) Sure.

You must answer the question before continuing

Continue

Slide 2 - Introduction

LEPS

U2L03HW

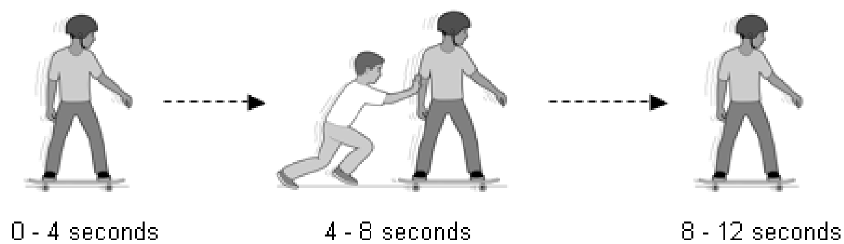
Pushing a Skateboarder - Introduction

In this homework activity, you will practice using your developing ideas about how the motion of an object is related to the force acting on it. Imagine you see your friend **coasting** toward you on his skateboard. (How he started moving is not a concern here.)

- From the moment you first see him, it takes 4 seconds for him to reach you.

As he reaches you, you begin to push him in the same direction as his motion with a **constant strength push**. You continue to push in this manner for 4 seconds and then you stop pushing.

- Your friend continues to move, coasting in the same direction, for a further 4 seconds.



Note: In this activity, we will assume the skateboard is well lubricated, so that the effects of friction can be ignored.

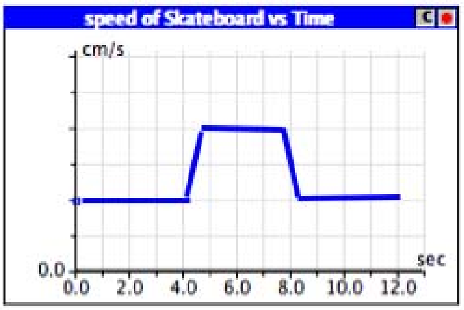
Continue

Slide 3 - Speed time graphs

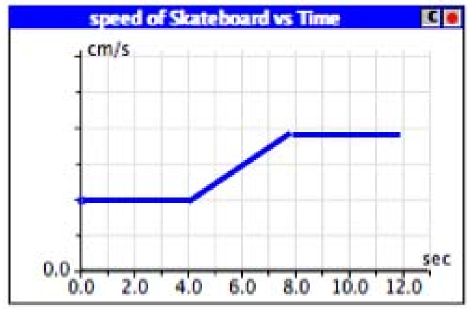
Pushing a Skateboarder - Speed-time graph idea

What do you think the motion of your friend would be like (speeding up, slowing down, or constant speed) during each of the 4-second periods described above? Which of these speed-time graphs best represents your thinking? (Remember, we are ignoring the effects of friction).

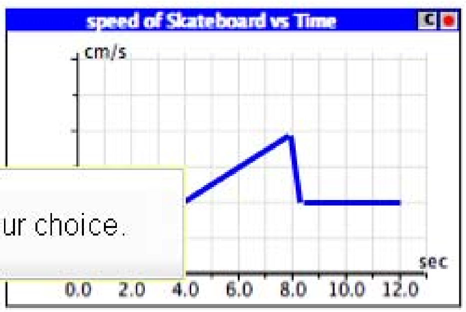
A)



B)



C)



Click on your choice.

You must answer the question before continuing

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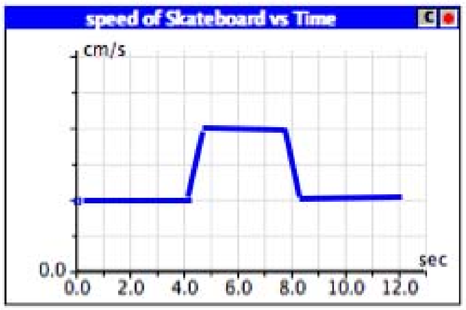
Slide 4 - Slide 4

Pushing a Skateboarder - Speed-time graph idea

You chose graph A.



Which of the following statements best represents the reasoning behind your choice?

- (•) A) His speed depends on the strength of the force pushing him forward. Before and after the push, the only force is the one that got him started. During the push, he has more force, so his speed is higher.
- ( ) B) When he is not being pushed, the skateboarder moves at a slow constant speed, but the force of the push makes him move at a faster constant speed.
- ( ) C) I don't like the reasoning in either A or B

Click on your choice.

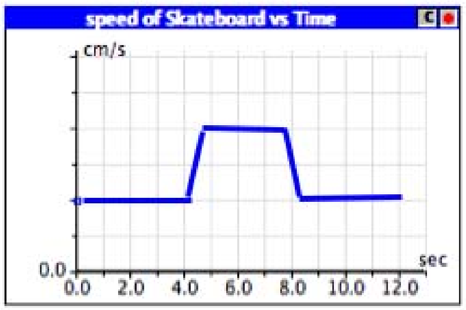
You must answer the question before continuing

Help | Clear | Skip | Back | Continue

Slide 5 - Slide 5

Pushing a Skateboarder - Speed-time graph idea

You chose graph A.



Feedback:

A/B: Your choice of graph and reasoning seem to imply that you think that when a constant force acts on an object, it will move at a constant speed. Is this idea supported by the evidence you saw in Lessons 2 & 3?

C: Perhaps your own reasoning would better fit with another of the speed-time graphs? Let's wait and see what happens in the rest of the activity.

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Slide 6 - Slide 6

Pushing a Skateboarder - Speed-time graph idea

You chose graph B.

Which of the following statements best represents the reasoning behind your choice?

- (•) A) When he is not being pushed, he moves at a constant speed. During the push, he continuously speeds up.
- ( ) B) During the push, more force is gradually transferred to the cart, adding to the force it already has, and so making it move faster.
- ( ) C) I don't like the reasoning in either A or B.

Click on your choice.

You must answer the question before continuing

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Slide 7 - Slide 7

Pushing a Skateboarder - Speed-time graph idea

You chose graph B.

Feedback:

A: Your choice of graph and reasoning seem to imply that you think a push is not required for an object to move at a constant speed, but that when it is being pushed, an object speeds up. Are these ideas supported by the evidence you saw in Lessons 2 & 3?

B: Your choice of graph and reasoning seem to imply that you think force is something that can be transferred between objects. Is this idea supported by the evidence you saw in Lessons 1 & 2?

C: Perhaps your own reasoning would better fit with another of the speed-time graphs? Let's wait and see what happens in the rest of the activity.

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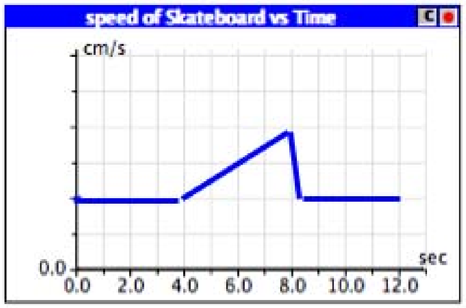
Slide 8 - Slide 8

Pushing a Skateboarder - Speed-time graph idea

You chose graph C.



Which of the following statements best represents the reasoning behind your choice?

- A) The push makes him gradually speed up, but as soon as the push stops, he slows down to his original speed because the force of the push is no longer acting.
- B) When he is not being pushed, he moves at a constant speed. During the push, he continuously speeds up, but once the push ends, he quickly slows back down to his original speed because the pushing force that was transferred to the cart quickly runs out.
- C) I don't like the reasoning in either A or B.

You must answer the question before continuing

Click on your choice.

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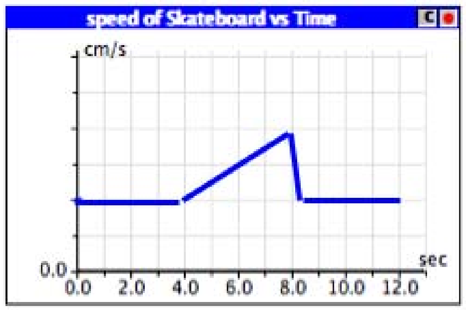
Slide 9 - Slide 9

Pushing a Skateboarder - Speed-time graph idea

You chose graph C.



Feedback:

A/B: Your choice of graph and reasoning seem to imply that you think that when a push stops acting on an object, it will quickly slow down. Is this idea supported by the evidence you saw in Lessons 1 & 2?

C: Perhaps your own reasoning would better fit with another of the speed-time graphs? Let's wait and see what happens in the rest of the activity.

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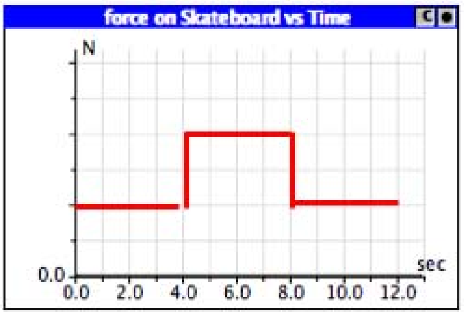
Slide 10 - Force time graphs

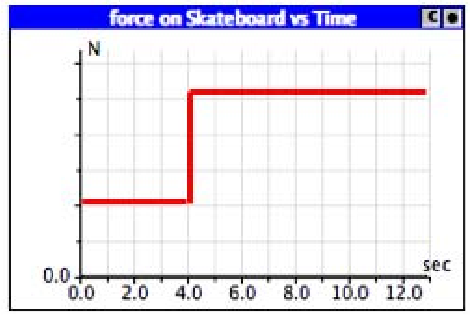
Pushing a Skateboarder - Predicting the force-time graph

Suppose you could measure the strength of any force that is pushing the skateboarder forward and plot it on a graph of force strength versus time. Which of the graphs below best represents what you think the force graph would look like for the skateboarder over the whole 12-second period?

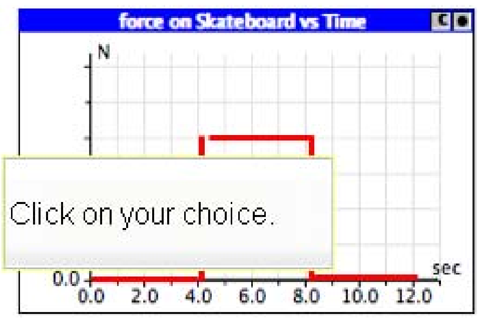
A)



B)



C)



Click on your choice.

You must answer the question before continuing

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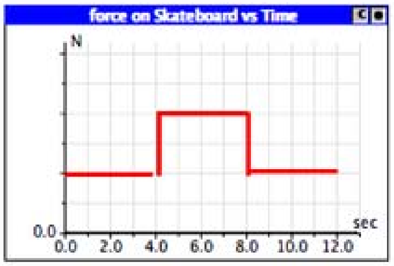
Slide 11 - Slide 11

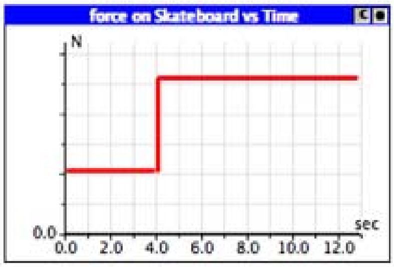
Pushing a Skateboarder - Predicting the force-time graph

Suppose you could measure the strength of any force that is pushing the skateboarder forward and plot it on a graph of force strength versus time. Which of the graphs below best represents what you think the force graph would look like for the skateboarder over the whole 12-second period?

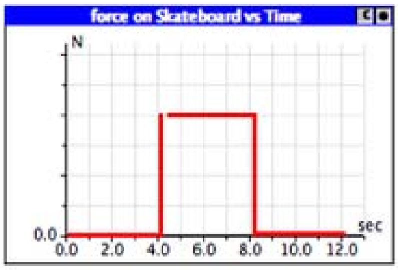
A)



B)



C)



Feedback:

A: Your choice of graph seems to imply that you think that when an object is moving, there must be a force pushing it forward. Is this idea supported by the evidence you saw in Lessons 1 & 2?

B: Your choice of graph seems to imply that you think that when an object is pushed, the force is transferred to it and continues with it even after the push has ended. Is this idea supported by the evidence you saw in Lessons 1 & 2?

C: Your choice of graph seems to imply that a force only pushes on an object when it interacts with another object. Is this idea supported by the evidence you saw in Lessons 1 & 2?

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Slide 12 - Simulator exploration

Pushing a Skateboarder - Checking your ideas

Simulator Exploration. You will watch a movie of a simulation of the skateboarder to check your thinking.* Click one of the buttons below to open the movie in a new window or tab. (Don't run the movie until you ***finish*** reading the text below the button!)

Windows QuickTime

The simulator setup shown at the start of the movie should show both speed-time and force-time graphs for the skateboarder. Also note the clock in the upper left. When you run the movie, a push will be applied to the skateboarder between 4 and 8 seconds.

Now watch the movie.

When you are finished, click the 'Continue' button below. **Do not close the movie window yet as you will need to look at the graphs to answer the questions on the following pages.**

*The computer program that runs the simulation is called the *Interactions & Motion Simulator*. You've already seen this simulator in action several times in class.

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Slide 13 - Slide 13

Pushing a Skateboarder - Interpreting the simulator results

Two students were discussing what the results from the simulator mean.

Student 1: I think the simulator shows that there is only a force acting on the skateboarder while he is being pushed. Before and after the push there is no force acting on him. That's why his motion during the push is different from before and after.

Student 2: I agree there's a force during the push, but I think there must also be some force before and after the push because he's moving forward during those periods too.

Which student's thinking do the simulator results support?

- (•) A) Student 1
- ( ) B) Student 2

Click on your choice.

You must answer the question before continuing

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Slide 14 - Slide 14

Pushing a Skateboarder - Interpreting the simulator results

Two students were discussing what the results from the simulator mean.

Student 1: I think the simulator shows that there is only a force acting on the skateboarder while he is being pushed. Before and after the push there is no force acting on him. That's why his motion during the push is different from before and after.

Student 2: I agree there's a force during the push, but I think there must also be some force before and after the push because he's moving forward during those periods too.

Which student's thinking do the simulator results support?

A) Student 1

B) Student 2

Feedback:

A. This student's thinking seems to be consistent with the simulator results, as the force-time graph is indeed at zero both before and after the push. Also, the motion is different (speeding up) during the push than it is before and after (constant speed).

B. You should look at the simulator results again. The force-time graph reads zero before and after the push, meaning there is no force pushing the skateboarder forward at those times.

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Slide 15 - Slide 15

Pushing a Skateboarder - Interpreting the simulator results

Two more students were discussing the simulator results.

Student 3: The simulator shows us that the force is transferred from the pusher to the skateboarder. That's why he is moving faster after the push, because he has more force pushing him forward.

Student 4: I disagree. It looks to me like when there's a force pushing him forward, he speeds up, but when there's no force, his speed is constant.

Which student's thinking do the simulator results support?

- A) Student 3
- B) Student 4 (selected)

Click on your choice.

You must answer the question before continuing

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Slide 16 - Slide 16

Pushing a Skateboarder - Interpreting the simulator results

Two more students were discussing the simulator results.

Student 3: The simulator shows us that the force is transferred from the pusher to the skateboarder. That's why he is moving faster after the push, because he has more force pushing him forward.

Student 4: I disagree. It looks to me like when there's a force pushing him forward, he speeds up, but when there's no force, his speed is constant.

Which student's thinking do the simulator results support?

A) Student 3

B) Student 4

Feedback:

A. You should look at the simulator results again. The force-time graph reads zero after the push, meaning there is no force pushing the skateboarder forward at that time. You may also want to take a look back at Lessons 1 & 2 to see whether the evidence you saw in those lessons supports or refutes the idea that force can be transferred between objects.

B. This student's thinking does seem to be supported by the simulator results, and also by the evidence you saw in Lessons 1 & 2.

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Slide 17 - Quiz

Quiz - Introduction

You should answer the following questions based on what you learned during this homework activity. Report your answers separately according to the instructions given you by your instructor. Keep this homework open in a separate browser window until you finish answering all the questions.

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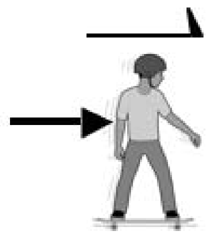
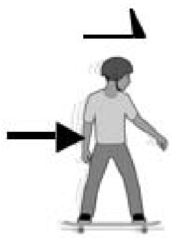
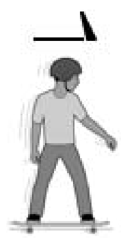
Quiz - Question 1

Shown below is a force diagram for the skateboarder at a time of 6 seconds after the simulator started (halfway through the period during which he was being pushed).



Which of the following force diagrams would be most appropriate for him at a time of 2 seconds (well before the push started)?

1) 

2) 

3) 

A) Left image

B) Center image

C) Right image

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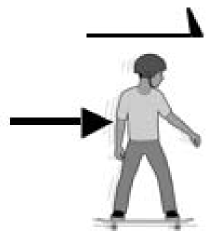
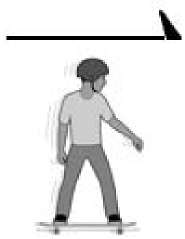
Quiz - Question 2

Shown below is a force diagram for the skateboarder at a time of 6 seconds after the simulator started (halfway through the period during which he was being pushed).

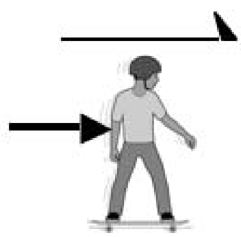


Which of the following force diagrams would be most appropriate for him at a time of 10 seconds (well after the push has ended)?

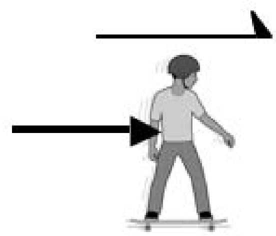
1)



2)



3)



A) Left image

B) Center image

C) Right image

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Slide 20 - Slide 20

Quiz - Question 3

Suppose you are watching an ice-hockey game with some classmates. As the puck is sliding across the ice at a relatively constant speed, it passes close to a player, who hits it (with his stick) in the same direction that it is already moving. After the hit, you notice that the puck is moving much faster than it was before the hit. Your classmates propose the following three explanations for why the puck is moving faster after the hit than before.

Student 1: The force of the stick was transferred to the puck during the hit. After the hit, the puck has more force, so it moves faster.

Student 2: The puck still has the force that started it moving, which is what keeps it moving at a constant speed. When the player hits it, he adds to this force, which makes the puck speed up. After the hit, this extra force is gone, so the puck stops speeding up; but the original force is still there, so now if moves at a faster constant speed.

Student 3: While the stick is in contact, it applies a force to the puck that makes it speed up. As soon as contact is lost, this force disappears, so the puck stops speeding up.

Whose reasoning do you agree with?

A) Student 1

B) Student 2

C) Student 3

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Quiz - Question 4

In Unit 1, you saw how contact push/pull interactions can be described using ideas of energy transfer and changes. In this unit, you are developing ideas about how these same interactions can be described in terms of the forces acting on an object.

Below is a list of ideas about how the energy and force descriptions of contact push/pull interactions might be related. Check all the boxes next to those statements that are consistent with the evidence you have seen so far. (To get credit for this question, you need to check all of those that are appropriate; partial credit is not available, so be careful!)

A) When a single force acts on a moving object in the same direction as its motion, its kinetic energy increases.

B) When a single force acts on a moving object in the same direction as its motion, mechanical energy is transferred out of the object to another object.

C) When a single force acts on a moving object in the same direction as its motion, the object is the energy receiver in a contact push/pull interaction.

D) If the kinetic energy of a moving object is staying constant, a force must be pushing it forward, even if the effects of friction can be ignored.

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